

EXHIBIT 11

**IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF MASSACHUSETTS**

DePuy Mitek, Inc.)	
a Massachusetts Corporation)	
)	
Plaintiff,)	
)	
v.)	Civil No. 04-12457 PBS
)	
Arthrex, Inc.)	
a Delaware Corporation and)	
)	
Pearsalls Ltd.,)	
a Private Limited Company)	
of the United Kingdom,)	
)	
Defendants.)	

**Declaration of Dr. Matthew Hermes In Support of
DePuy Mitek's Claim Interpretation of the Hunter Patent**

I. Background Information

A. Professional Experience

1. From 1983-95, I was employed with U. S. Surgical Corp. In 1983, I started as Senior Research Scientist. My duties from 1983-1986 included developing products based on bio-absorbable materials for use as medical devices. From 1986-1992, I initiated and led the first suture development program at U.S. Surgical. That program led to the commercialization of the Syneture™ suture product line. My responsibilities included all phases of surgical suture development from concept to commercialization. My suture group included seventeen team members directly involved in the design and development of commercial surgical suture products, including design and manufacture, fiber extrusion and processing, fiber design, yarn design, braiding specifications, selection of materials, braid design, prototype braiding, braid

post treatment, stretching, annealing, coating, packaging design, sterilization, testing, cooperating with regulatory department concerning 510(k) approval, and quality control.

2. In 1996, I authored the book "Enough for One Lifetime," the biography of Wallace Carothers, the inventor of Nylon. While writing this book from 1989-1996, I researched and studied the origins of synthetic fiber science including the history and development of nylon and polyester.

3. Before I worked at U.S. Surgical Corporation, I was a Research Director at Virginia Chemicals, at Celanese Co. from 1979-1983. Prior to being a Research Director, I was a Research Chemist, Supervisor, at E. I. DuPont from 1959-1979. At DuPont, I work with triaxial support systems and supervised a group that worked on elastomer coated fabrics.

From 1992-1994, I was an Adjunct Professor of Chemistry at the University of Wyoming.

From 1995-1997, I was a Consultant at Colorado Advanced Technology Institute.

In 2001 and 2006 I received two Small Business grants from the NIH for the development of unique all plastic manual wheelchairs and worked with Turbo Wheelchair company to develop, manufacture, and sell these unique devices.

B. Education

4. I have a Bachelor of Science in Chemistry from St. John's University, Brooklyn, NY, 1955. I have a Ph. D. in Chemistry from the University of Maryland, 1959. My mentor was Professor William Bailey who developed one of the earliest polymer science research groups in the country. My doctoral thesis related to polymers made using the Diels-Alder reaction. I also have a Masters of Arts in Liberal Studies from Wesleyan University, 1992.

5. A copy of my CV is attached under Tab A. A list of my publications and patents are set forth in my CV.

II. PERSONS OF ORDINARY SKILL IN THE ART WOULD UNDERSTAND THE CLAIMED PE TO INCLUDE ULTRA HIGH MOLECULAR WEIGHT PE

6. The Hunter Patent reasonably conveys to one of skill in the art and would convey to anyone with any familiarity with polymers that the inventors had possession of a claimed suture with ultra high molecular weight polyethylene (PE) as the first-fiber forming material. The first fiber-forming materials recited in Claim 1 – PTFE, FEP, PFA, PVDF, PETFE, PP and PE – are all polymeric materials. In other words, they are molecules formed of repeating chemical units, called “monomers.” Polyethylene (PE), for example, is formed from repeating units of the monomer ethylene, ($\text{CH}_2=\text{CH}_2$). The polyethyelene (PE) may be referred to as $(\text{CH}_2\text{CH}_2)_n$, where n = a whole number and indicates the number of repeating monomeric units of ethylene in the polymer.

7. The length of the chain of repeating units in a polymer (i.e., how high a number “ n ” is) determines the “molecular weight” of the polymer. The longer the chain (the higher “ n ” is), the higher the molecular weight of the polymer. Polymers are frequently referred to as having “low,” “high,” or, in some situations, “ultra high” molecular weights. Ultra high molecular weight PE has the same monomer as any other polyethylene, ethylene, ($\text{CH}_2=\text{CH}_2$). “High molecular weight” or “ultra high molecular weight” PE is just a longer chain of the repeating ethylene monomer (i.e., n is a higher number) than “low molecular weight” or “medium molecular weight” PE.

8. In 1987, the Encyclopedia of Polymer Science and Engineering 2nd edition volume 10 recognized polyethylene as the “common (source-based)” name for all polymers made from ethylene (Tab B). The International Union of Pure Applied Chemistry (IUPAC), which has long been recognized as the world authority on chemical nomenclature, officially recognized that PE is the accepted abbreviations for all types of PE (Tabs B & C). Thus, one of

skill in the art would have known that “PE” or “polyethylene” as used in the Hunter Patent means all polymers from ethylene including ultra high molecular weight PE.

9. The Hunter Patent specifically claims “PE.” Further, the Hunter Patent expressly describes “polyethylene (PE)” (Tab D, Hunter Patent at 4:27-30). One of skill in the art would have known that “PE” means “polyethylene” and means all polymers made from ethylene. PE is the generic name for all types of PE, including ultra high molecular weight PE.

10. A person of skill in the art would likely be a scientist in chemistry or a chemical, mechanical, or biomedical, biomechanical, or textile engineer (or other similar technical field) practicing in the field of suture design or development and having about 2 to 3 years of experience in the suture design field or person without such a degree but having about eight years experience in suture design or development. I am a person of skill in the art.

11. The Hunter Patent’s description of PE is consistent with all types of PE. The Hunter Patent states that in a preferred embodiment the first set of yarns acts as lubricating yarns (Tab D, Hunter Patent at 4:11-12). PE including ultra high molecular weight PE is a lubricious yarn (Tab E at 52:24-53:2).

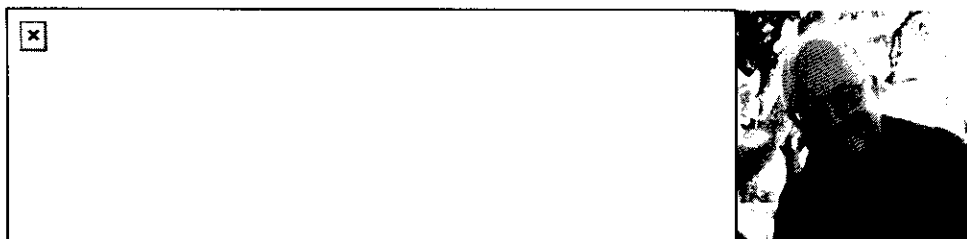
12. The Hunter Patent states that the first set of yarns may be derived from “non-absorbable polymers.” PE including ultra high molecular weight PE is a non-absorbable polymer. The Hunter Patent also describes the first set of yarns as being made from fiber forming materials (Tab D, Hunter Patent at 4:30-32). PE including ultra high molecular weight PE is a fiber forming material. Therefore, the Hunter Patent’s description of PE is consistent with the meaning of PE and includes ultra high molecular weight PE.

I declare under penalty of perjury that the foregoing is true and correct.

Date Executed: August 11, 2006

/s/ Matthew E. Hermes, Ph.D.

TAB A



Curriculum Vitae

Matthew E. Hermes, Ph. D.
76 Meridian Rd.
Beaufort, SC 29907

404-729-0758
hayden@islc.net

Profile:

Dr. Hermes is a scientist, inventor, fundraiser, biographer, educator and public servant with 50 years successful scientific research experience. He evaluates patterns of relationships - whether scientific, cultural or technical - and synthesizes novel and practical solutions to tough, real-world problems. Now he serves as Secretary/Treasurer of Turbo Wheelchair, Co., Inc., (Dr. Jane Hermes startup Company) and also:

- Actively consults in chemistry of biomedical devices and on intellectual property matters for small and FORTUNE 50 companies.
- Writes and initiates business plans for startup enterprises including advising and writing SBIR grant proposals.
- Maintains and publishes new systems of chemical education for university students through the award winning ChemCases.com web site and the ALSOS digital library.
- Consults on the processes affecting public education boards from his experience as an elected Public School Board member.

Recent Accomplishments

- As entrepreneur, Principal Investigator, applied for and received \$750,000 (2001) and \$100,000 (2006) NIH Small Business Innovative Research grants for design, development, prototype manufacture of durable, solid seat, folding engineering resin adult and children's manual wheelchairs (Merlexi Craft, see Merlexi.com).
- In wheelchair development made 20 design changes from first prototype, designed and built steel molds, manufactured 200 prototype wheelchairs for domestic demonstration, obtained FDA approval and manufactures commercial product. Chair most durable ever tested at University of Pittsburgh Human Engineering Research Laboratory. US Patent has been allowed. (US Application 20050098970).
- Project Director, ChemCases.Com, National Science Foundation-funded University General Chemistry curriculum development project. Written and published two ChemCases. More than 4.3 million pages delivered. Cited for excellence by SCIENCE, Scientific American and the WASHINGTON TIMES.

DePuy Mitek, Inc. v. Arthrex, Inc.
C.A. No.04-12457 PBS

MH000276

Earlier Accomplishments:

- At US Surgical Corp. through 1995, initiated and led research and development leading to introduction of absorbable polyester fiber sutures among 1,000+ suture products for the Company. Conceptualized, created and prototyped products. Designed, built and operated manufacturing.
- Discovered and patented and introduced practical methods for stabilizing moisture sensitive polyester fibers against hydrolysis. Invention reduced time to market introduction by five years.
- Envisioned and patented non-protein polymer systems incorporating unique features of predetermined length, composition and sequence. These distinctive properties in proteins drive all living systems.
- Obtained 27 patents in the surgical device/absorbable resin/suture field including seven dealing with polyester hydrolysis and its control.
- As Adjunct Professor of Chemistry at Wyoming, developed synthetic methods for structural assembly of polyesters with predetermined sequence. Monodisperse oligomers show protein-like configuration.
- Completed biography "Enough for One Lifetime, Wallace Carothers, Inventor of Nylon", published by the American Chemical Society March 1996.
- As Contract Consultant to Colorado Advanced Technology Institute, taught Applied Telecommunications to twelve rural Colorado governments and entities. Actively developing and maintaining four World-Wide-Web Internet sites with over 150 documents. AeRie presentation of Rural telecommunications chosen "Pick of the Week", May 1, 1995 by NCSA. Developed and managed web communications for Dept. of Commerce TIIAP GIS development grant.
- Marketing resort lodging through Internet connectivity, developing electronic marketing data and plans, 1995-1998. Commercial internet marketing resulted in \$2.25M new business for Yampa Valley, Colorado.
- Elected to Steamboat Springs, Colorado RE-2 Board of Education, 1997-2000.
- Completed digitizing the 1881 "Atlas of Colorado". Produced CDROM of maps and western art as educational and recreational resource for the US Forest Service.
- Consultant in public board of education "policy governance" with Aspen Group International.
- At Virginia Chemicals, unraveled mystery of large industrial explosion and rationalized thermochemistry of the inorganic paper chemical, sodium hydrosulfite. Directed design engineering research for diallylamine plant.
- At DuPont solved the thirty-year problem of hydrolytic moisture degradation of abrasion resistant coatings for transparent acrylic sheet. Obtained 4 US patents on hydrolysis-resistant coatings as result of this work.
- At DuPont Central Research, discovered the chemistry of the treacherously explosive cyanogen azide. Developed safe handling methods and described mechanism of ring-chain tautomerisms and skeletal rearrangements.
- With Prof. William Bailey at Maryland, produced monomers and polymers demonstrating polymerization through Diels-Alder polymerization.

United States Patents: (31)

3,642,681(1972) Polysilicic Acid Coatings
 3,714,214(1973) Alkoxy Silyl Alkyl Compounds
 3,775,171(1973) Article Coated with Polysilicic Acid
 3,781,251(1973) Alkoxy Silyl Alkyl Compounds and Polymers
 4,744,365(1988) Compositions for Absorbable Surgical Devices
 4,839,130(1989) Process of Absorbable Surgical Device

DePuy Mitek, Inc. v. Arthrex, Inc.
C.A. No.04-12457 PBS

MH000277



4,844,854(1989) Process for Making a Surgical Device Using Two-Phase Compositions
 5,019,093(1991) Braided Suture
 5,037,429(1991) Improving the Stability of Braided Sutures
 5,051,272(1991) Improving the Stability of a Polymeric Article
 5,124,103(1992) Two Phase Compositions for Absorbable Surgical Devices
 5,222,978(1993) Packaged Synthetic Absorbable Surgical Elements
 5,226,912(1993) Combined Surgical Needle-Braided Suture Device
 5,248,761(1993) Amino Acid Polyesters of Predetermined Sequence
 5,256,762(1993) Polyesters of Predetermined Monomeric Sequence
 5,261,886(1994) Cabled Core and Braided Suture Made Therefrom
 5,282,829(1994) Hollow Body Implants
 5,306,289(1994) Braided Suture of Improved Characteristics
 5,312,437(1994) Absorbable Coating Compositions
 5,320,624(1994) Blends of Glycolide and/or Lactide Copolymers
 5,349,047(1994) Polyesters Having Predetermined Sequence
 5,366,081(1994) Packaged Synthetic Surgical Suture Elements
 5,424,136(1995) Polymers of 1,3 Dioxolane-4-ones
 5,447,966(1995) Coating Surgical Articles
 5,456,697(1995) Cabled Core and Braided Suture Made Therefrom
 5,462,162(1995) Packaged Synthetic Absorbable Surgical Elements
 5,468,252(1995) Packaged Synthetic Absorbable Surgical Elements
 5,472,702(1995) Sterilization of Growth Factors
 5,475,063(1995) Polymer Blends
 6,228,954(2001) Blends of glycolide and/or lactide polymers and caprolactone and/or trimethylene carbonate polymers and absorbable surgical devices made therefrom
 6,260,699(2001) Packaged, Synthetic Absorbable Suture Elements

Publications:

- ChemCases.com in the Classroom, American Chemical Society meeting, San Francisco, CA, March 30, 2000
- ChemCases Modular Curriculum as Distance Learning Tool, American Chemical Society Meeting, Anaheim, CA, March 23, 1999
- Gatorade as Case Study Curriculum Supplement, American Chemical Society Meeting, Dallas, TX, April 2, 1998.
- Gatorade, Why We Drink that Pale Yellow Stuff, Presentation at Kennesaw State University, Sept. 30, 1997.
- Carothers, A Man Clinging to His Craft, Presentations to the Delaware Section, American Chemical Society, April 17, 1996, the Middle Atlantic Regional Meeting, American Chemical Society, May 23, 1996 and the Delaware Section, American Institute of Chemical Engineering, Jan. 23, 1997.
- TV presentation, Science Odyssey, WGBH, Boston (January 14, 1998)
- TV Presentation, City University of New York's *Science and the Written Word* (Jan. 24, 1997).
- The Ineluctable Fate of Carothers, Chemistry and Industry, April 15, 1996
- "Enough for One Lifetime, Wallace Carothers, Inventor of Nylon", biography of the inventor Wallace H. Carothers, American Chemical Society, March 1996.
- DuPont Hires Carothers, Presentation at the Atlanta meeting of the American Chemical Society, Spring 1992.
- Synthetic Fibers from "Pure Science": DuPont Hires Carothers, Manmade Fibers, Their Origin and Development, ed. R. Seymour and R. Porter, Elsevier Applied Science, London, 1993, p. 227-243.
- Wallace Carothers, Inventor of Nylon, Presentation to the San Francisco Psychobiography Group, Jan. 14, 1993.
- Wallace Carothers, Inventor of Nylon, Presentation to the Wyoming Section of the American Chemical Society, April 27, 1993.
- Polyesters of Predetermined Sequence, with Dr. Bin Huang, Journal of Polymer Science, Vol. 33, p.1419(1995).



DePuy Mitek, Inc. v. Arthrex, Inc.
 C.A. No.04-12457 PBS

MH000278

- W. J. Bailey, M. E. Hermes et al., Journal of Organic Chemistry, 27,1975(1962), 27,2732(1962), 27,3295(1962), 28,1724(1963), 29,1254(1964).
- F. D. Marsh and M. E. Hermes, Journal of the American Chemical Society, 86,4506(1964)
- F. D. Marsh and M. E. Hermes, Journal of the American Chemical Society, 87,1819(1965)
- M. E. Hermes and R. A. Braun, Journal of Organic Chemistry, 31,2568(1966)
- M. E. Hermes and F. D. Marsh, Journal of the American Chemical Society, 89,4760(1967)
- M. E. Hermes and F. D. Marsh, Journal of Organic Chemistry, 37,2969(1972)

Education:

- B. S. Chemistry, St. John's University, Brooklyn, NY, 1955.
- Ph. D., Chemistry, University of Maryland, 1959.
- M. A., Liberal Studies, Wesleyan University, 1992.

Employment History:

- Research Chemist, Supervisor, E. I. DuPont, 1959-79.
- Research Director, Virginia Chemicals, Celanese Co., 1979-83.
- Corporate Research Scientist, U. S. Surgical Corp., 1983-94.
- Adjunct Professor, University of Wyoming, 1992-1994
- Consultant, Colorado Advanced Technology Institute, 1995-7
- President, F. V. Hayden Institute, 1996-present
- Adjunct Professor, Kennesaw State University, 1997-2002
- Turbo Wheelchair, Principal Investigator, 2001-2003
- Turbo Wheelchair, Secretary-Treasurer, 2003-Present

Personal

Married, Excellent Health.

Member Beaufort Rotary, American Chemistry Society, American Association for the Advancement of Science

4/07/2006

DePuy Mitek, Inc. v. Arthrex, Inc.
C.A. No.04-12457 PBS

MH000279



TAB B



US005314446A

United States Patent [19][11] **Patent Number:** **5,314,446****Hunter et al.**[45] **Date of Patent:** **May 24, 1994**[54] **STERILIZED HETEROGENEOUS BRAIDS**[75] **Inventors:** Alastair W. Hunter, Bridgewater;
Arthur Taylor, Jr., Plainfield, both of
N.J.; Mark Steckel, Maineville, Ohio[73] **Assignee:** Ethicon, Inc., Somerville, N.J.[21] **Appl. No.:** 838,511[22] **Filed:** Feb. 19, 1992[51] **Int. Cl.:** D04C 1/00[52] **U.S. Cl.:** 606/231; 606/228;
87/7; 87/9; 428/370[58] **Field of Search** 606/228, 230, 231;
87/7, 8, 9; 428/225[56] **References Cited****U.S. PATENT DOCUMENTS**

3,187,752 6/1965 Glick 128/335.5
 3,463,158 8/1969 Schmitt et al. 606/228
 3,527,650 9/1970 Block 117/7
 3,636,956 1/1972 Schneider 128/335.5
 3,942,532 3/1976 Hunter et al. 128/335.5
 4,043,344 8/1977 Landi et al. 128/335.5
 4,047,533 8/1977 Perciaccante et al. 128/335.5
 4,052,988 10/1977 Doddi et al. 128/335.5
 4,141,087 2/1979 Shalaby et al. 3/1
 4,470,941 9/1984 Kurtz 264/136

4,624,256 11/1986 Messier et al. 128/335.5
 4,946,467 8/1990 Ohi et al. 606/228
 4,959,069 9/1990 Brennan et al. 606/228
 4,979,956 12/1990 Silverstrini 623/13
 5,116,360 5/1992 Pinchuk et al. 623/1
 5,147,400 9/1992 Kaplan et al. 623/13

FOREIGN PATENT DOCUMENTS

2949920 3/1981 Fed. Rep. of Germany A61F
 1/00
 WO86/00020 1/1986 PCT Int'l Appl. A61L 17/00
 2082213 8/1980 United Kingdom .
 2218312A 11/1989 United Kingdom A01K 91/00

Primary Examiner—George F. Lesmes**Assistant Examiner**—Chris Raimund**Attorney, Agent, or Firm**—Hal Brent Woodrow[57] **ABSTRACT**

Heterogeneous braided multifilament of first and second set of yarns mechanically blended by braiding, in which first and second set of yarns are composed of different fiber-forming materials.

Heterogeneous braids are useful for preparation of surgical sutures and ligatures.

12 Claims, 3 Drawing Sheets

U.S. Patent

May 24, 1994

Sheet 1 of 3

5,314,446

FIG-1

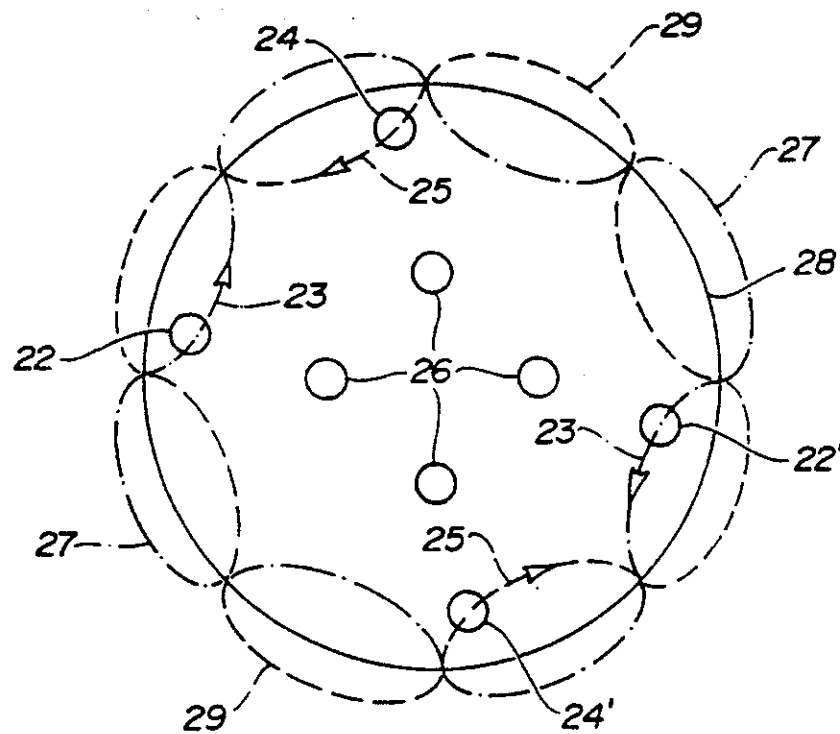
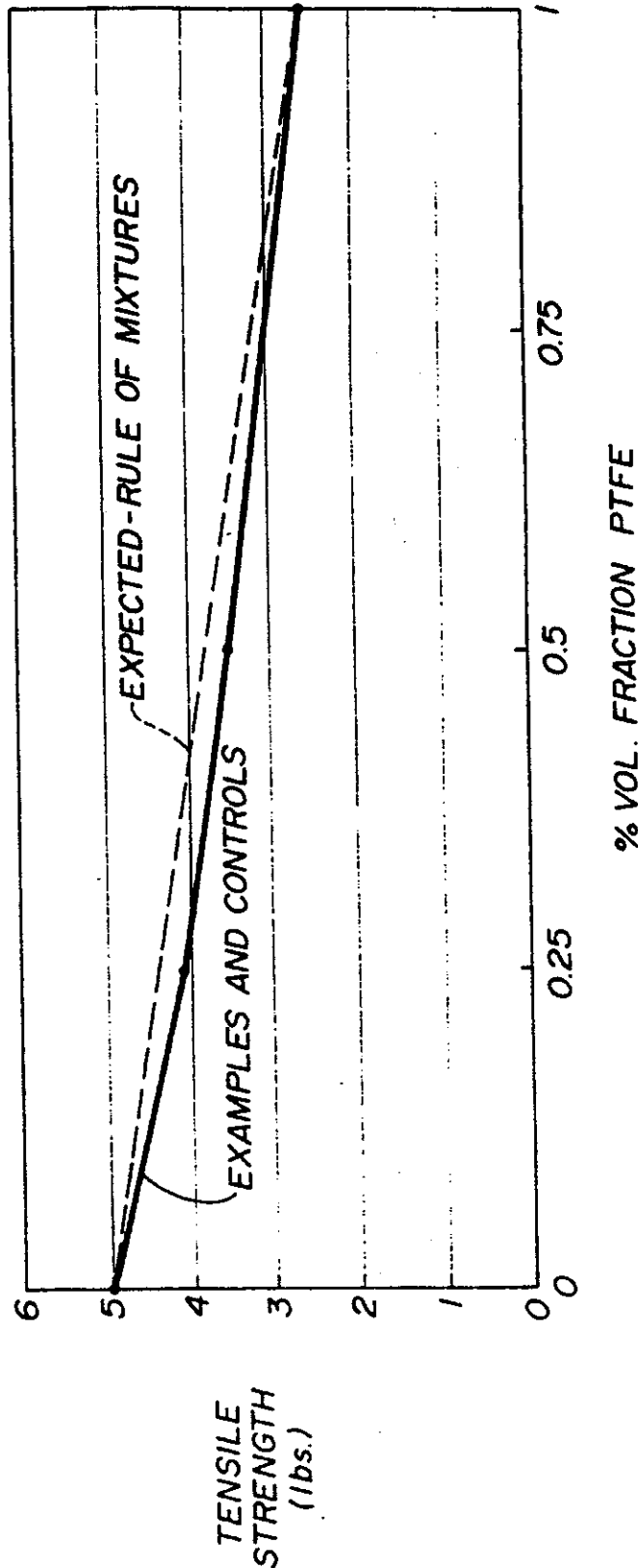


FIG-2



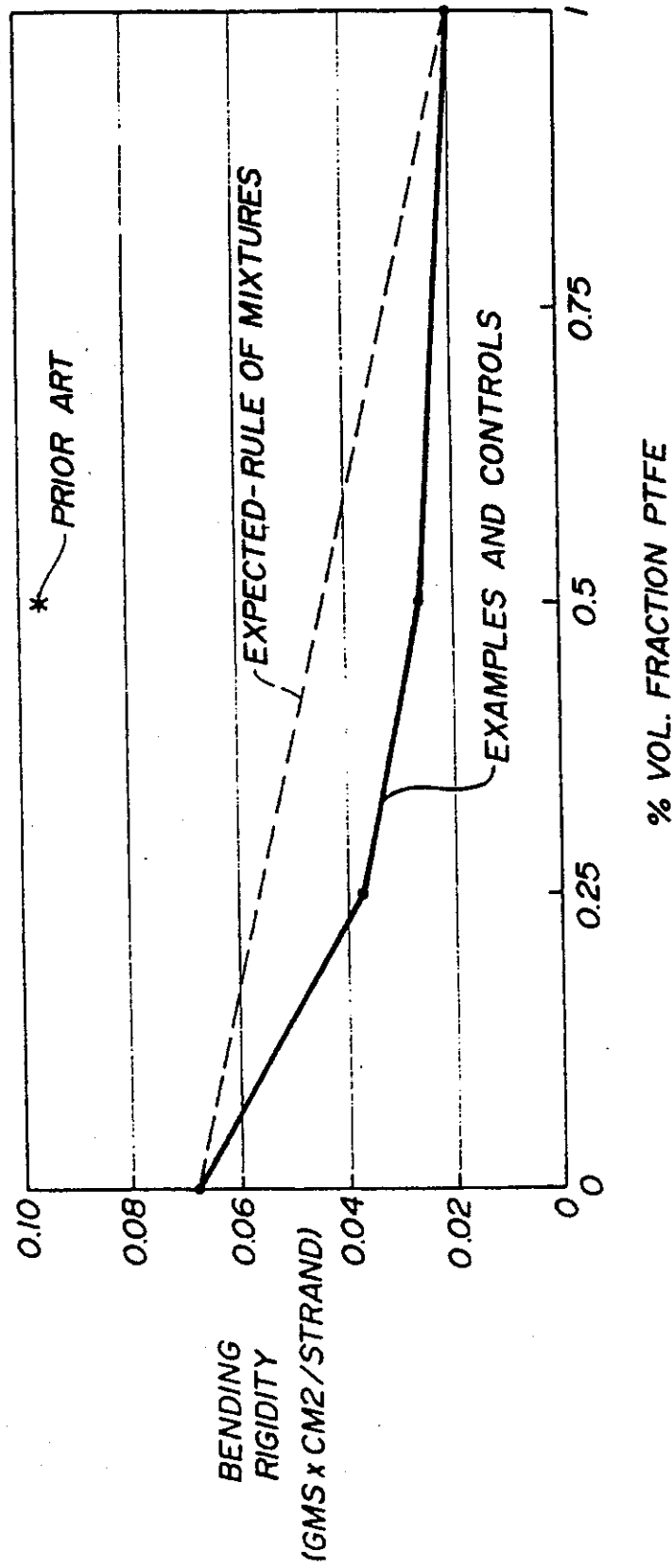
U.S. Patent

May 24, 1994

Sheet 3 of 3

5,314,446

FIG-3



5,314,446

1

STERILIZED HETEROGENEOUS BRAIDS

BACKGROUND OF THE INVENTION

This invention relates to braided multifilaments, and especially to sterilized, braided multifilaments suitably adapted for use as surgical sutures or ligatures.

Braided multifilaments often offer a combination of enhanced pliability, knot security and tensile strength when compared to their monofilament counterparts. The enhanced pliability of a braided multifilament is a direct consequence of the lower resistance to bending of a bundle of very fine filaments relative to one large diameter monofilament. However, for this enhancement to be realized, the individual multifilaments must be able to bend unencumbered or unrestricted by their neighboring filaments. Any mechanism which reduces this individual fiber mobility, such as simple fiber-fiber friction, a coating which penetrates into the braid interstices, or a melted polymer matrix which adheres fibers together, will adversely affect braid pliability. In the extreme case where the multifilaments are entirely bonded together, the pliability or bending resistance closely approximates that of a monofilament.

Unfortunately, the prior art abounds with attempts to improve specific properties of multifilament braids at the expense of restricting the movement of adjacent filaments which make up the braid. For example, multifilament sutures almost universally possess a surface coating to improve handling properties.

U.S. Pat. No. 3,942,532 discloses a polyester coating for multifilament sutures. The preferred polyester coating is polybutylate, which is the condensation product of 1,4-butanediol and adipic acid. U.S. Pat. No. 4,624,256 discloses a suture coating copolymer of at least 90 percent ϵ -caprolactone and a biodegradable monomer, and optionally a lubricating agent. Examples of monomers for biodegradable polymers disclosed include glycolic acid and glycolide, as well as other well known monomers typically used to prepare bioabsorbable coatings for multifilament sutures.

An alternative to the use of the commonly accepted coating compositions for multifilament sutures to improve handling properties is disclosed in U.S. Pat. 3,527,650. This patent discloses a coating composition of polytetrafluoroethylene (PTFE) particles in an acrylic latex. Although the PTFE particles act as an excellent lubricant to decrease the surface roughness of multifilament sutures, the particles have a tendency to flake off during use. Also, this particular coating is a thermoset which requires a curing step for proper application.

More recently, a dramatic attempt has been made to create a monofilament-like surface for a multifilament suture. U.S. Pat. No. 4,470,941 discloses the preparation of "composite" sutures derived from different synthetic polymers. The composite suture is composed of a core of low melting fibers around which are braided high melting fibers. Because of the lack of cohesiveness of the dissimilar fibers, the low melting fibers in the core are melted and redistributed throughout the matrix of the braided, high melting fibers. Although these composite sutures represent an attempt to combine the best properties of different synthetic fibers, it unfortunately fails in this respect due to increased stiffness (as evidenced by FIG. 3 which is described in detail below),

2

apparently due to the reduction of fiber mobility resulting from the fusing of the fibers together.

Another attempt to enhance the properties of multifilament sutures can be found in WO 86/00020. This application discloses coating an elongated core of a synthetic polymer having a knot tenacity of at least 7 grams/denier with a film-forming surgical material. The film-forming surgical material can be absorbable or nonabsorbable, and can be coated on the elongated core by solution casting, melt coating or extrusion coating. Such coated multifilament sutures suffer from the same deficiencies which plague conventionally coated multifilament sutures.

All of the attempts described in the prior art to improve braid properties have overlooked the importance of fiber-fiber friction and its impact on fiber mobility and braid pliability. The properties of concern here include the fiber-fiber frictional coefficients (which frequently relate to the polymer's surface energy), the fiber cross-sectional shape and diameter, and the braid structure which influences the transverse forces across the braid. If fibers composed of highly lubricious polymers are used in the traditional manner, then a highly pliable braid can be prepared. However, in most cases, these braids will be relatively weak and unusable. Hence, a tradeoff between braid strength and pliability exists in the design of conventional braided multifilaments.

In view of the deficiencies of the prior art, it would be desirable to prepare multifilament sutures exhibiting improved pliability and handling properties. More specifically, it would be most desirable to prepare braided multifilaments composed of dissimilar fiber-forming materials in which the fiber-forming materials contribute significantly to enhanced pliability for the braided multifilament without appreciably sacrificing its physical properties.

SUMMARY OF THE INVENTION

The invention is a heterogeneous braid comprising a first and second set of continuous and discrete yarns in a sterilized, braided construction. At least one yarn from the first set is in direct intertwining contact with a yarn from the second set.

Each yarn from the first set is composed of a plurality of filaments of a first fiber-forming material, and each yarn from the second set is composed of a plurality of filaments of a second fiber-forming material.

Surprisingly, the heterogeneous braids may exhibit a combination of outstanding properties attributable to the specific properties of the dissimilar fiber-forming materials which make up the braided yarns. The dissimilar fiber forming materials do not require melt bonding or any other special processing techniques to prepare the heterogeneous braids of this invention. Instead, the integrity of the braid and therefore its properties is due entirely to the mechanical interlocking or weaving of the individual yarns. In fact, it is possible to tailor the physical and biological properties of the braid by varying the type and proportion of each of the dissimilar fiber forming materials used, as well as adjusting the specific configuration of the braid. For example, in preferred embodiments, the heterogeneous braid will exhibit improved pliability and handling properties relative to that of conventional homogeneous fiber braids, without sacrificing physical strength or knot security.

The sterilized, heterogeneous braids of this invention are useful as surgical sutures or ligatures, as well as for

5,314,446

3

the preparation of any other medical device which would benefit from its outstanding physical or biological properties.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a carrier layout for the preparation of a heterogeneous braid within the scope of this invention;

FIG. 2 is a plot representing the relationship between the tensile strength of heterogeneous and homogeneous braids of polyethylene terephthalate (PET) and PTFE yarns, and the volume fraction of PTFE yarns in the braids; and

FIG. 3 is a plot representing a relationship between the initial bending rigidity of heterogeneous and homogeneous braids of PET and PTFE yarns, and the volume fraction of PTFE yarns in the braids.

DETAILED DESCRIPTION OF THE INVENTION

For purposes of describing this invention, a "heterogeneous" braid is a configuration composed of at least two sets of dissimilar yarns mechanically blended by intertwining the dissimilar yarns in a braided construction. The yarns are continuous and discrete, so therefore each yarn extends substantially along the entire length of the braid and maintains its individual integrity during braid preparation, processing and use.

The heterogeneous braids of this invention can be conventionally braided in a tubular sheath around a core of longitudinally extending yarns, although such a core may be excluded, if desired. Braided sheath sutures with central cores are shown in U.S. Pat. Nos. 3,187,752; 4,043,344; and 4,047,533, for example. A core may be advantageous because it can provide resistance to flattening, as well as increased strength. Alternatively, the braids of this invention can be woven in a spiral or spiroid braid, or a lattice braid, as described in U.S. Pat. Nos. 4,959,069 and 5,059,213.

The dissimilar yarns of the first and second set of yarns are braided in such a manner that at least one yarn from the first set is directly intertwined with, or entangled about, a yarn from the second set. Direct mechanical blending of individual, dissimilar yarns therefore occurs from the interweaving and interlocking of these dissimilar yarns, enhancing yarn compatibility and the overall physical and biological properties of the heterogeneous braid. Preferably, every yarn from the first set is in direct intertwining contact with a yarn of the second set to achieve the maximum degree of mechanical blending of the dissimilar yarns.

The first and second fiber-forming materials which make up the filaments of the first and second set of yarns, respectively, can be any materials capable of being spun into continuous filaments. Advantageously, the fiber-forming materials are nonmetallic.

The preferred fiber-forming materials are synthetic fiber-forming polymers which are melt or solution spun through a spinneret to prepare continuous filaments. The filaments so prepared are advantageously stretched to provide molecular orientation and annealed to enhance dimensional stability and/or biological performance. The fiber-forming polymers can be bioabsorbable or nonabsorbable, depending on the particular application desired. Examples of monomers from which bioabsorbable polymers are derived include, but are not limited to, some hydroxyacids and lactones, e.g. glycolic acid, lactic acid, glycolide, lactide, p-dioxanone,

4

ϵ -caprolactone and trimethylene carbonate, as well as copolymers and polymer blends derived from these monomers and others. Interestingly, numerous bioabsorbable heterogeneous braids exhibiting varying useful biological properties, such as breaking strength retention in vivo and the absorption profiles in vivo, can be prepared for specific applications by using different combinations of bioabsorbable polymers.

Preferably, the continuous filaments which make up the first and second set of yarns are derived from nonabsorbable polymers. In a preferred embodiment, the first set of yarns acts as lubricating yarns to improve the overall pliability, or compliance, and surface lubricity of the heterogeneous braid. Preferably, the fiber-forming material of the first set exhibits a surface energy (which frequently relates to surface lubricity) less than about 38 dyne/cm, as measured by contact angle of liquids on polymer surfaces, as described by Kissa, E., "Handbook of Fiber Science and Technology," Vol. II, Part B, Marcel Dekker, 1984. Such fiber forming polymers include perfluorinated polymers, e.g. PTFE and fluorinated ethylene/propylene copolymers (FEP) and perfluoroalkoxy (PFA) polymers, as well as non-perfluorinated polymers such as polyvinylidene fluoride (PVDF), polyethylene/tetrafluoroethylene copolymers (PETFE), the polychlorofluoroethylene polymers, polypropylene (PP) and polyethylene (PE). More preferably, the first fiber-forming material exhibits a surface energy less than about 30 dyne/cm. The preferred polymers for the first set are PTFE, PETFE, FEP, PE and PP, and the most preferred fiber forming polymer is PTFE.

In a more preferred embodiment, the lubricating yarns of the first set are mechanically blended with yarns of the second set which act to provide improved strength to the heterogeneous braid. Preferably, the second set of yarns exhibits a yarn tenacity greater than 3.0 grams/denier, more preferably greater than 5.0 grams denier. The preferred yarns are PET, nylon and aramid, and the most preferred yarns are PET.

In the most preferred embodiment, the heterogeneous braid is composed of a first set of PTFE yarns mechanically blended with a second set of PET yarns in a braided configuration. Advantageously, the braided sheath encloses a core of longitudinally extending PET yarns to further improve the overall strength and resistance to flattening of the heterogeneous braid. In this embodiment, the volume fraction of lubricating yarns in the braided sheath and core desirably ranges from about 20 to about 80 percent. A volume fraction of lubricating yarns below about 20 percent will not typically improve the pliability of the braid, and a volume fraction above about 80 percent may adversely affect the overall strength of the braid. The filament fineness for such a heterogeneous braid is preferably less than 10 denier per filament, preferably from about 0.5 to about 5 denier per filament. A more coarse filament may result in a stiffer braid. The preferred individual yarn denier is between 10 and 100 denier.

The heterogeneous braids of this invention can be prepared using conventional braiding technology and equipment commonly used in the textile industry, and in the medical industry for preparing multifilament sutures. For example, the first and second set of yarns can be interwoven as indicated by the plan view of the yarn carrier layout of FIG. 1 for the preparation of a braided multifilament. The individual yarns of the braided sheath feed from spools mounted on carriers 22, 22' and

5,314,446

5

24, 24'. The carriers move around the closed circular loop 28, moving alternately inside and outside the loop 28 to form the braiding pattern. One or more carriers are continually following a serpentine path in a first direction around the loop, while the remaining carriers are following a serpentine path in the other direction.

In the illustrated embodiment, carriers 22, 22' are travelling around serpentine path 27 in a clockwise direction as indicated by directional arrows 23, and carriers 24, 24' are travelling around serpentine path 29 in a counterclockwise direction as indicated by arrows 25. The moving carriers dispense yarns which intertwine to form the braid. The yarns from all the carriers in a constructed embodiment of FIG. 1 are dispensed upward with respect to the plane of the drawing, and the braid is taken up on a reel located above the plane of the drawing.

In one embodiment, moving carriers 22, 24 dispense yarns of the first set and moving carriers 22', 24' dispense yarns of the second set to form the heterogeneous braid. In a more preferred embodiment, moving carriers 22, 22' dispense yarns of the first set and moving carriers 24, 24' dispense yarns of the second set. This carrier layout provides a braid in which each yarn of the first set is directly intertwined with a yarn from the second set.

Advantageously, as illustrated in FIG. 1, disposed within the center of the loop 28 are carriers 26 which dispense the core yarns of the braid. In the most preferred embodiment of this invention, moving carriers 22, 22' dispense PTFE yarns, moving carriers 24, 24' dispense PET yarns, and core carriers 26 dispense PET yarns.

Numerous additional embodiments are contemplated within the scope of the invention using conventional braiding technology and equipment. For example, the carrier layout can be modified to prepare a braid configuration using from 3 to 28 sheath carriers, with or without any number of core yarns. Dissimilar yarns from the first and second set of yarns can be plied together using conventional techniques before braiding, and in this embodiment, the carriers can dispense identical bobbins of plied yarns composed of individual yarns from the first and second sets. This embodiment not only offers the advantage of inter-yarn mechanical blending, but also the intimate mixing associated with intra-yarn blending.

Similar to the preparation of conventional homogeneous braids, the yarns from which the heterogeneous braids are prepared are preferably nontextured. The yarn tension during braiding is advantageously adjusted so that the yarn elongation for each set of yarns is about equal. The equilibration of yarn elongation may prevent irregularities, for example, "core popping", which is the tendency of core yarns to break through the braided sheath as the braid is bent. The number of picks per inch in the finished braid can be adjusted to balance the tensile strength of the braid with braid quality, e.g. the tendency for core popping and overall braid smoothness.

After the heterogeneous braid is prepared, it is desirably scoured to remove machine oils and lubricants, and any foreign particles. The scoured braid is preferably stretched at a temperature between the glass transition temperature and melting temperature of the lower melting set of yarns. Therefore, the stretching temperature is such that none of the yarns is actually melted. The stretching operation densifies the braid and improves

6

braid smoothness. Afterwards, the braid may be annealed while under restraint to improve dimensional stability, and in the case of absorbable braids, to improve the breaking strength retention in vivo.

If desired, the surface of the heterogeneous multifilament braid can be coated with a bioabsorbable or nonabsorbable coating to further improve the handleability and knot tiedown performance of the braid. For example, the braid can be immersed in a solution of a desired coating polymer in an organic solvent, and then dried to remove the solvent. Most preferably, the coating does not cause the fibers or yarns to adhere to one another increasing stiffness. However, if the surface of the heterogeneous braid is engineered to possess a significant fraction of the lubricious yarn system, the conventional coating may be eliminated saving expense as well as avoiding the associated braid stiffening.

If the surface of the braid is coated, then the coating composition may desirably contain bioactive materials such as antibiotics and growth factors.

The post-treated heterogeneous braid is sterilized so it can be used for a host of medical applications, especially for use as a surgical suture, preferably attached to a needle. The braid can be sterilized using any of the conventional techniques well known in the art. For example, sterilization can be effected by exposing the braid to gamma radiation from a cobalt 60 source. Alternatively, the braid can be sterilized by exposure to ethylene oxide.

In the following examples, the tensile properties and knot security are each determined using an Instron Tensile Tester. The tensile properties, i.e. the straight and knot tensile strength and the percent elongation, are determined generally according to the procedures described in U.S. Pat. No. 4,838,267. The knot security, which provides an indication as to the number of throws required to secure a knot so that it fails to slip before cleanly breaking, is measured by first tying a conventional square knot around a mandrel, pulling the knot apart on the Instron Tester to observe whether slipping occurs, and if so, then tying knots with additional throws until 20 out of 20 knots break cleanly without slipping. The bending rigidity, which is the inverse of pliability, is determined using a Kawabata Pure Bending Tester, as discussed in "The Effects of Structure on the Geometric and Bending Properties of Small Diameter Braids", Drexel University Master Thesis, 1991, by Mr. E. Ritter.

The examples are illustrative only, and are not intended to limit the scope of the claimed invention. The types of yarns used to prepare the heterogeneous braid and the yarn geometry can be varied to prepare heterogeneous braids within the scope of the claimed invention which exhibit a combination of outstanding physical or biological properties.

EXAMPLES

Examples I and II describe heterogeneous braids of PTFE and PET yarns. In order to evaluate the relative performance of these braids, two controls are included which represent 100% PET and 100% PTFE braids, respectively. To the extent possible, the yarn materials and processing conditions are identical for the controls and heterogeneous braid examples. In addition, for comparison purposes, a braid is fabricated with identical materials but processed per the prior art U.S. Pat. No. 4,470,941.

7

CONTROL I

FIBER MATERIALS: An 8×0 PET braid is fabricated, i.e. 8 sheath yarns and 0 core yarns. All yarns are Dupont Dacron PET, 70 denier, 48 filament, type 52 yarn.

PROCESSING: The yarns are wound on braider

5,314,446

8

PROCESSING: Identical to EXAMPLE I, except that the hot stretch temperature is at 300° C. and for a longer residence time to facilitate melting of the PET fibers.

The properties of CONTROLS I and II, and EXAMPLES I and II, and the PRIOR ART I are summarized in the following Table:

	USP DIAMETER (mils)	TENSILE STRENGTH (lbs)	KNOT STRENGTH (lbs)	BENDING RIGIDITY (gm × cm ²)	KNOT STABILITY (# of throws)
CONTROL I	10.68	4.98	3.14	0.0680	4
CONTROL II	9.11	2.58	2.04	0.0196	7
EXAMPLE I	9.71	3.55	2.41	0.0257	5
EXAMPLE II	10.35	4.10	2.67	0.0371	5
PRIOR ART I	8.81			0.0966	

bobbins per conventional methods, and the bobbins loaded on each carrier of a N.E. Butt 8 carrier braider. Machine settings include: 32 pick gear, 0.009" wire tension springs, and 183 rpm. The braid is aqueous scoured, and hot stretched at 30% draw ratio at 225° C.

CONTROL II

FIBER MATERIALS: An 8×0 PTFE braid is fabricated. All yarns are Dupont Teflon, 110 denier, 12 filament.

PROCESSING: The yarns are wound on braider bobbins per conventional methods, and the bobbins loaded on each carrier of a N.E. Butt 8 carrier braider. Machine settings include: 36 pick gear, no tension springs, and 183 rpm. The braid is scoured and hot stretched per the conditions described in CONTROL I.

EXAMPLE I

FIBER MATERIALS: An 8×0 heterogeneous braid is fabricated, consisting of four PET 70 denier yarns and four PTFE 110 denier yarns. The yarns are identical to that employed in CONTROL I and II. On a volume basis, the braid is 50.3% PET, and 49.7% PTFE.

PROCESSING: Four bobbins of PET yarn and four bobbins of PTFE yarn were wound by conventional means. The PET bobbins were loaded on the clockwise moving carriers of the N.E. Butt 8 carrier braider, and the PTFE yarn bobbins on the counter-clockwise moving carriers. Machine settings include: 32 pick gear, 0.009" tension springs on PET carriers, no springs on PTFE carriers, and 183 rpm. The braid is scoured and hot stretched per the conditions described in CONTROL I.

EXAMPLE II

FIBER MATERIALS: Identical to EXAMPLE I, except that 6 PET yarns and 2 PTFE yarns were used. On a volume basis, the braid is 75.5% PET, and 24.5% PTFE.

PROCESSING: Identical to EXAMPLE I, except that 2 PET bobbins replace 2 PTFE bobbins. All other braider machine settings, scour and hot-stretch conditions are identical to CONTROL I and II and EXAMPLE I.

PRIOR ART I

FIBER MATERIALS: Identical to EXAMPLE I. On a volume basis, the braid is 50.3% PET, and 49.7% PTFE.

As may be expected, the tensile strengths of the heterogeneous braid examples reflect the relative contributions of the individual components. This behavior is said to follow the "rule of mixtures", i.e. the composite property is a weighted average of the component properties. In equation form,

$$P_c = (V_f a) (P_a) + (V_f b) (P_b)$$

where P_c is a composite property (such as tensile strength or modulus), P_a and P_b are the properties of the components a and b, and $V_f a$ and $V_f b$ are the volume fractions of components a and b. This behavior is clearly observed in FIG. 2, which shows a plot of tensile strength versus volume fraction of PTFE yarns for the Examples and Controls, in relation to the expected plot according to the rule of mixtures.

Surprisingly, the bending rigidity of the heterogeneous braids in EXAMPLES I and II do not follow the rule of mixtures, and show an enhanced bending rigidity relative to the weighted average of its components. This is shown in FIG. 3 as a plot of bending rigidity versus %PTFE in the braids. Bending rigidity is the inverse of pliability, and is obtained by measuring the slope of the bending moment-radius of curvature plot of a suture strand in pure bending. Hence lower bending rigidity relates to a more pliable suture, which is a highly desirable property. The mechanism of this enhanced pliability is believed to be internal lubrication of the braid by the "solid lubricant" behavior of the low surface energy PTFE.

U.S. Pat. No. 4,470,941 discloses the preparation of a "composite" suture with a monofilament-like surface made from multifilament yarns. The composite suture is composed of two different synthetic polymer fibers, which is thermally processed to melt one of the fibers to form a continuous matrix. This process was utilized to produce the PRIOR ART I example, the data of which is shown in Table 1 and FIG. 3. It is observed that the melting of the PET fibers significantly increases the braid bending rigidity due to the bonding of the "non-melted" fibers together, hence resulting in a less pliable braid of diminished utility.

What is claimed is:

1. A surgical suture consisting essentially of a heterogeneous braid composed of a first and second set of continuous and discrete yarns in a sterilized, braided construction wherein at least one yarn from the first set is in direct intertwining contact with a yarn from the second set; and

5,314,446

9

- a) each yarn from the first set is composed of a plurality of filaments of a first fiber-forming material selected from the group consisting of PTFE, FEP, PFA, PVDF, PETFE, PP and PE; and
 - b) each yarn from the second set is composed of a plurality of filaments of a second fiber-forming material selected from the group consisting of PET, nylon and aramid; and
 - c) optionally a core.
2. The surgical suture of claim 1 wherein the suture is attached to a needle.
3. The surgical suture of claim 1 wherein the first fiber-forming material exhibits a surface energy less than about 38 dynes/cm.
4. The surgical suture of claim 3 wherein the first fiber-forming material exhibits a surface energy less than about 30 dynes/cm.
5. The surgical suture of claim 4 wherein the first set of yarns is PTFE.

10

6. The surgical suture of claim 5 wherein the second set of yarns exhibits a yarn tenacity greater than 3.0 grams/denier.

7. The surgical suture of claim 6 wherein the second set of yarns exhibits a yarn tenacity greater than 5.0 grams/denier.

8. The surgical suture of claim 1 wherein the second set of yarns is PET.

9. The surgical suture of claim 8 wherein the volume fraction of the first set of yarns in the braided sheath and core ranges from about 20 to about 80 percent.

10. The surgical suture of claim 9 wherein the fiber fineness of the yarns of the first and second sets is less than 10 denier per filament.

11. The surgical suture of claim 1 wherein at least one yarn from the first set of yarns is plied together to a yarn from the second set of yarns.

12. The surgical suture of claim 8 wherein the suture is attached to a needle.

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TAB C

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ENCYCLOPEDIA OF POLYMER SCIENCE AND ENGINEERING

VOLUME 10

Molecular Weight Determination
to
Pentadiene Polymers

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NOMENCLATURE

Nomenclature, as used in this article, refers to the naming of polymeric materials. The nomenclature of scientific communication is emphasized, although there is generally little reason for differences between scientific and other, eg, commercial, usage.

Since the publication of the first edition of this Encyclopedia, the International Union of Pure and Applied Chemistry (IUPAC) has established the Commission on Macromolecular Nomenclature, which is now the leading nomenclature body in the polymer field. The Commission is promulgating a series of rules and definitions that are placing polymer nomenclature on a much more systematic basis than had previously been the case (Table 1) (1-21). The International Standardization Organization (ISO), primarily through its Technical Committee TC/61 Plastics, and various national nomenclature bodies (such as that of the American Chemical Society) are also helping to shape the field. Recent issues of *Chemical Abstracts* are additional authoritative sources of polymer nomenclature.

At the present time, the IUPAC Commission on Macromolecular Nomenclature is developing a set of definitions for many of the basic terms dealing with polymer molecules, assemblies of polymer molecules, polymer solutions, polymer crystals, polymer melts and solids, polymerization reactions, etc. It is also extending existing nomenclature to more complicated cases, such as cross-linked polymers. When this phase of the work is completed by the late 1980s, the naming of polymers and polymer terminology will have become largely systematized and, following the IUPAC practice in other fields of chemistry, a compendium of polymer nomenclature rules will be published.

Table 1. IUPAC Publications on Polymer Nomenclature

Title	Comment	Refs.
Report on Nomenclature in the Field of Macromolecules	obsolete	1
Report on Nomenclature Dealing with Steric Regularity in High Polymers	superseded by Ref. 2	3
Revised Report on Nomenclature Dealing with Steric Regularity in High Polymers	superseded by Ref. 4	2,5
Report of the Committee on Nomenclature of the International Commission on Macromolecules	obsolete	6
Basic Definitions of Terms Relating to Polymers		7,8
List of Standard Abbreviations (Symbols) for Synthetic Polymers and Polymer Materials (1974)	superseded by Ref. 9	10
Use of Abbreviations for Names of Polymeric Substances	Recommendations 1986	9
Nomenclature of Regular Single-Strand Organic Polymers		11
Stereochemical Definitions and Notations Relating to Polymers	Provisional Recommendations 1980	12 4
Nomenclature for Regular Single-Strand and Quasi Single-Strand Inorganic and Coordination Polymers	Provisional Recommendations 1984	13 14
Note on the Terminology for Molar Masses in Polymer Science		15-17
Source-Based Nomenclature for Copolymers		18
Definitions of Terms Relating to Individual Macromolecules, Their Assemblies, and Dilute Polymer Solutions		19
Definitions of Terms Relating to Crystalline Polymers		20
A Classification of Linear Single-Strand Polymers		21

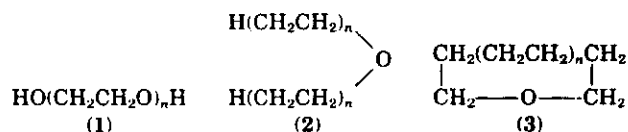
Basic Definitions

No nomenclature document is more fundamental to a given science than the definitions of basic terms used in that area. The IUPAC Commission on Macromolecular Nomenclature published a document in 1974 (8) that offers definitions of 52 terms, including polymer, constitutional unit, monomer, polymerization, regular polymer, tactic polymer, block polymer, graft polymer, monomeric unit, degree of polymerization, addition polymerization, condensation polymerization, homopolymer, copolymer, bipolymer, terpolymer, copolymerization, and many others. Both structure-based and process-based definitions are given.

Source-based Nomenclature

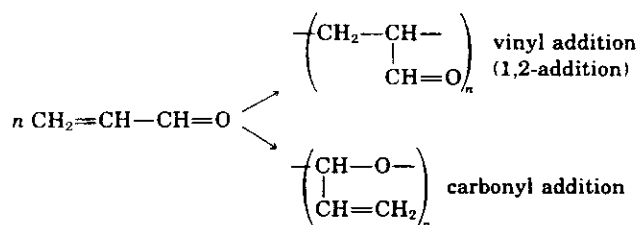
Traditionally, polymers have been named by attaching the prefix poly to the name of the real or assumed monomer (the "source") from which it is derived.

Thus polystyrene is the polymer made from styrene and will often be found in an index under "styrene, polymer of." When the name of the monomer consists of two or more words, parentheses should be used (1), as in poly(vinyl acetate), poly(methyl methacrylate), poly(sodium styrenesulfonate), etc. Failure to use parentheses can lead to ambiguity: polychlorostyrene can be the name of either a polychlorinated (monomeric) styrene molecule or a polymer derived from chlorostyrene; polyethylene oxide can refer to polymer (1), polymer (2), or the macrocycle (3).



These problems are easily overcome with parentheses; names such as poly(chloro)styrene, poly(chlorostyrene), and poly(ethylene oxide) clearly indicate the part of the name to which the prefix poly refers. The omission of parentheses is, unfortunately, quite common.

The principal deficiency of source-based nomenclature is that the chemical structure of the monomeric unit in a polymer is not identical with that of the monomer, eg, $-\text{CH}_2-\text{CHX}-$ vs $\text{CH}_2=\text{CHX}$; thus the name polymonomer is actually a misnomer. The structure of the repeating unit is also not specified in this scheme; for example, polyacrolein does not indicate whether the vinyl or the aldehyde group has polymerized (see ACROLEIN POLYMERS).



Different types of polymerization can take place with many other monomers, depending on the polymerization conditions. Furthermore, a name such as poly(vinyl alcohol) refers to a hypothetical source, since this polymer is obtained by hydrolysis of poly(vinyl acetate). In spite of these serious deficiencies, source-based nomenclature is still firmly entrenched in industrial literature and, to a lesser extent, in scientific communication. It originated at a time when polymer science was less developed and the structure of most polymers ill-defined. The rapid advances now being made in structural determination of polymers will gradually shift the emphasis of polymer nomenclature away from starting materials and toward the structure of the macromolecules.

Copolymers. Copolymers are polymers that are derived from more than one species of monomer (8). Because this is a process-based definition, source-based nomenclature can be easily adapted to the naming of copolymers (18). However, the arrangement of the various types of monomeric units must be specified. Seven types of arrangements have been defined and are shown in Table 2, where A, B, and C represent the names of monomers. The monomer names are linked through a connective (infix), such as *-co-*, to form the name of the copolymer, as in poly(styrene-*co*-acrylonitrile). The order of citation of the mono-

194 NOMENCLATURE

Vol. 10

mers is arbitrary, except for graft copolymers where the backbone monomer is named first.

An equally acceptable alternative scheme utilizes the prefix copoly followed by citation of the names of the monomers used, separated from each other by an oblique stroke. Parentheses are also needed. For example, copoly(styrene/butadiene) denotes an unspecified copolymer of styrene and butadiene. The other connectives of Table 2 are placed before such names to provide additional structural information, as in

stat-copoly(styrene/butadiene)
ran-copoly(ethylene/vinyl acetate)
alt-copoly(styrene/maleic anhydride)
per-copoly(ethylene phenylphosphonite/methyl acrylate/carbon dioxide)
block-copoly(styrene/butadiene/methyl methacrylate)
graft-copoly(styrene/butadiene)

It is not necessary to use parentheses to enclose vinyl acetate, maleic anhydride, methyl acrylate, etc, even though the name of each of these monomers consists of two words; the names of the polymers, as written here, are unambiguous.

The names of copolymers, derived either from the main scheme or the alternative, can be further modified to indicate various structural features. For example, the chemical nature of end groups can be specified as follows:

α -X- ω -Y-poly(A-*alt*-B)
 α -butyl- ω -carboxy-*block*-copoly(styrene/butadiene)

Whereas subscripts placed immediately after the name of the monomer or the block designate the degree of polymerization or repetition, mass and mole fractions and molar masses, which in most cases are average quantities, are expressed by placing corresponding figures after the complete name of the copolymer. The order of citation is as for the monomeric species in the name. Unknown quantities are designated by *a*, *b*, etc. Some examples follow.

A block copolymer containing 75 mass % of polybutadiene and 25 mass % of polystyrene is

polybutadiene-*block*-polystyrene (0.75:0.25 *w*) or
block-copoly(butadiene/styrene) (75:25 mass %)

A graft copolymer, consisting of a polyisoprene backbone grafted with isoprene and acrylonitrile units in an unspecified arrangement, containing 85 mol % of isoprene units and 15 mol % of acrylonitrile units is

polyisoprene-*graft*-poly(isoprene-co-acrylonitrile) (0.85:0.15 *x*) or
graft-copoly[isoprene/(isoprene;acrylonitrile)] (85:15 mol %)

A graft copolymer consisting of 75 mass % of polybutadiene with a relative molecular mass of 90,000 as the backbone and 25 mass % of polystyrene in grafted chains with a relative molecular mass of 30,000 would be

polybutadiene-*graft*-polystyrene (75:25 mass %; 90,000:30,000 *M_r*)

Table 2. IUPAC Nomenclature of Copolymers^a

Type	Arrangement of monomeric units	Structure	Connective	Example
unspecified statistical	unknown or unspecified obeys known statistical laws	(A-co-B) (A-stat-B)	-co- -stat-	poly(styrene-co-(methyl methacrylate)) poly(styrene-stat-acrylonitrile-stat-butadiene)
random alternating periodic	obeys Bernoullian statistics alternating sequence periodic with respect to at least three monomeric units	(A-ran-B) (AB) _n (ABC) _n (ABB) _n (AABB) _n (ABAC) _n	-ran- -alt- -per-	poly(ethylene-ran-(vinyl acetate)) poly(ethylene glycol)-alt-(terephthalic acid) poly(formaldehyde-per-(ethylene oxide)-per-(ethylene oxide))
block graft	linear arrangement of blocks polymetric side chain different from main chain ^c	—AAAA—BBBBB— —AAAAA—AAAAA— B B B B B	-block- ^b -graft- ^d	polystyrene-block-polybutadiene polybutadiene-graft-polystyrene

^a Main system of the IUPAC document (18); an alternative scheme is described in the text.^b The connective -b- has also been used.^c Main chain (or backbone) is specified first in the name.^d The connective -g- has also been used.

A graft copolymer in which the polybutadiene backbone has a DP of 1700 and the polystyrene grafts have an unknown DP is named

graft-copoly(butadiene/styrene) (1700:a DP)

The published IUPAC copolymer document (18) should be consulted for the names of more complex copolymers, eg, those having a multiplicity of grafts or having chains radiating from a central atom (see also BLOCK COPOLYMERS; COPOLYMERS, ALTERNATING; COPOLYMERIZATION; GRAFT COPOLYMERS).

Structure-based Nomenclature

For organic polymers that are regular, ie, have only one species of constitutional unit in a single sequential arrangement, and consist only of single strands, the IUPAC has promulgated a structure-based system of naming polymers (11). As originally devised by the Polymer Nomenclature Committee of the American Chemical Society (22), it consists of naming a polymer as poly(constitutional repeating unit), wherein the repeating unit is named as a bivalent organic radical according to the usual nomenclature rules for organic chemistry. It is important to note that in structure-based nomenclature the name of the constitutional repeating unit has no relationship to the source from which the unit was prepared. The name is simply that of the largest identifiable unit in the polymer, and locants for unsaturation, substituents, etc are dictated by the structure of the unit.

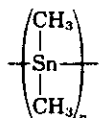
The steps involved in naming the constitutional repeating unit are (1) identification of the unit, taking into account the kinds of atoms in the main chain and the location of substituents; (2) orientation of the unit; and (3) naming of the unit. Examples of names for some common polymers are given in Table 3. Note that in this system parentheses are always used to enclose the repeating unit.

Structure-based nomenclature can be utilized to name polymers with great complexity, provided only that they be regular and single-stranded. Among these are polymers with constitutional repeating units which consist, themselves, of a series of smaller subunits; polymers with heteroatoms or heterocyclic ring systems in the main chain; and polymers with substituents on acyclic or cyclic subunits of constitutional repeating units. Structure-based nomenclature is also applicable to copolymers having a regular structure, regardless of the starting materials used, eg, poly(oxyethyleneoxyterephthaloyl). In principle, it should be possible to extend the existing structure-based nomenclature beyond regular, single-strand polymers to polymers that have reacted, cross-linked polymers, ladder polymers, and other more complicated systems.

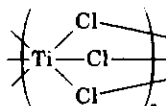
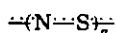
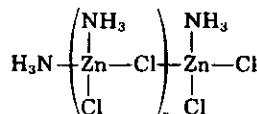
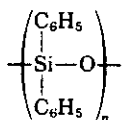
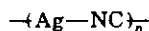
Structure-based nomenclature has gained acceptance in the scientific literature, eg, *Chemical Abstracts*, because it overcomes many of the deficiencies of source-based nomenclature.

Inorganic and Coordination Polymers. The nomenclature of regular single-strand inorganic and coordination polymers (qv) is governed by the same

fundamental principles as that for single-strand organic polymers (14). The name of such a polymer is that of the smallest structural repeating unit prefixed by the terms poly, *catena* (for linear chains) or other structural indicator, and designations for end groups. The structural units are named by the nomenclature rules for inorganic and coordination chemistry. Some examples are

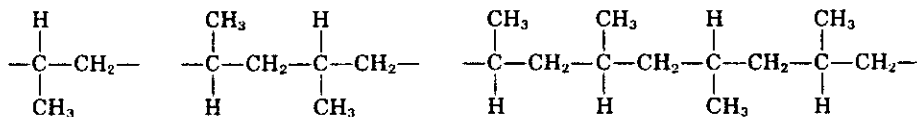


catena-poly(dimethyltin)

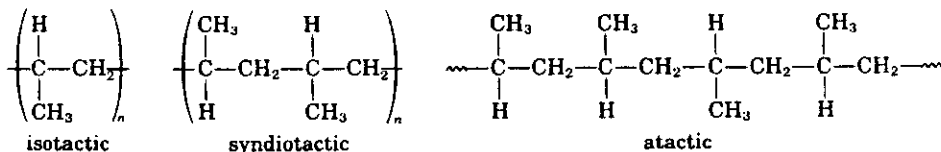
catena-poly[titanium-tri- μ -chloro]catena-poly(nitrogen- μ -thio) α -ammine- ω -(amminedichlorozinc)-
catena-poly[(amminechlorozinc)- μ -chloro]catena-poly[(diphenylsilicon)- μ -oxo]catena-poly[silver- μ -(cyano-*N*:C)]

Stereochemical Definitions and Notations. Structure-based nomenclature for regular polymers (4) can denote stereochemical features if the repeating unit used is the configurational unit, ie, a constitutional unit having one or more sites defined for stereoisomerism (8). Structure-based names are then derived in the usual fashion. The various stereochemical features that are possible in a polymer must be defined.

Natta and co-workers introduced the concept of tacticity, ie, the orderliness of the succession of configurational repeating units in the main chain of a polymer. For example, in poly(propylene), possible steric arrangements are shown in Fischer projections displayed horizontally:



and the corresponding polymers have the following structures:



The isotactic polymer has only one species of configurational unit in a single sequential arrangement and the syndiotactic polymer shows an alternation of configurational units that are enantiomeric, whereas in the atactic polymer the

Table 3. Examples of Systematic Structure-based Names for Polymers*

Structure	Structure-based name	Common (source-based) name
$\text{-(CH}_2\text{CH}_2\text{)}_n$	poly(methylene)	polyethylene
$\text{-(CHCH}_2\text{)}_n$	poly(propylene)	polypropylene
$\text{-(CH(CH}_3\text{))}_n$		
$\text{-(C(CH}_3\text{)}_2\text{)}_n$		
$\text{-(CH(CH}_3\text{)CH}_2\text{)}_n$	poly(1,1-dimethylethylene)	polyisobutylene
$\text{-(CH}_2\text{CH(CH}_3\text{)CH}_2\text{)}_n$	poly(1-methyl-1-butenylene)	polyisoprene
$\text{-(CH(CH}_3\text{)CH}_2\text{)}_n$	poly(1-phenylethylene)	polystyrene
$\text{-(CH(CH}_2\text{Cl)}_2\text{)}_n$	poly(1-chloroethylene)	poly(vinyl chloride)
$\text{-(CH(CH}_2\text{CN)}_2\text{)}_n$	poly(1-cyanoethylene)	polyacrylonitrile
$\text{-(CH(CH}_2\text{OOCCH}_3\text{)}_2\text{)}_n$	poly(1-acetoxyethylene)	poly(vinyl acetate)
$\text{-(CF}_2\text{)}_n$	poly(1,1-difluoroethylene)	poly(vinylidene fluoride)

polytetrafluoroethylene
poly(vinyl butyral)

poly(methyl methacrylate)

poly(ethylene oxide)

poly(phenylene oxide)

poly(ethylene terephthalate)

poly(hexamethylenediamine-co-adipic acid) or
poly(hexamethylene adipamide)
poly(maleic anhydride-co-styrene)

poly(difluoromethylene)

poly[(2-propyl-1,3-dioxane-4,6-diyl)methylene]

poly[1-(methoxycarbonyl)-1-methylethylene]

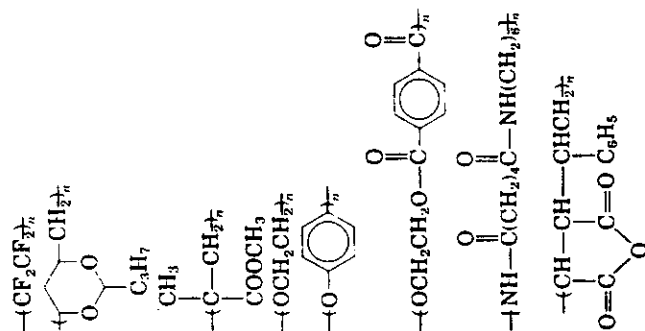
poly(oxyethylene)

poly(oxy-1,4-phenylene)

poly(oxyethyleneoxyterephthaloyl)

poly(iminoadipoyliminohexamethylene)

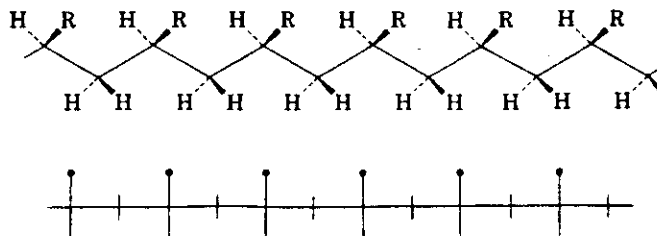
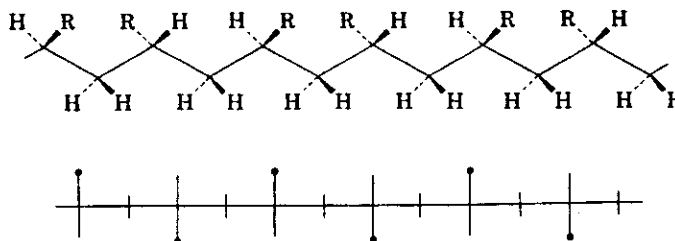
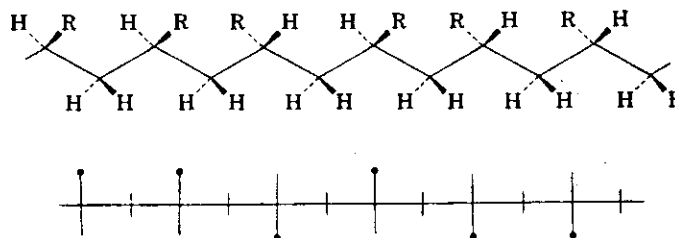
poly[2,5-dioxotetrahydrofuran-3,4-diyl(phenylethylene)]



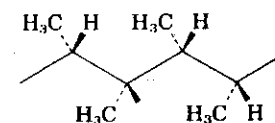
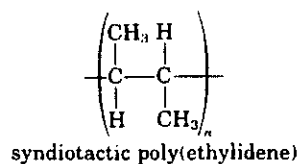
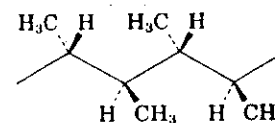
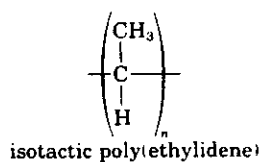
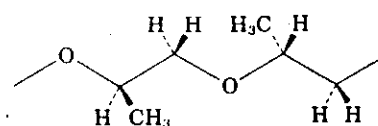
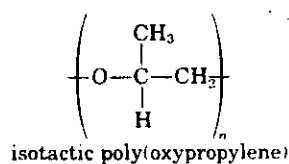
200 NOMENCLATURE

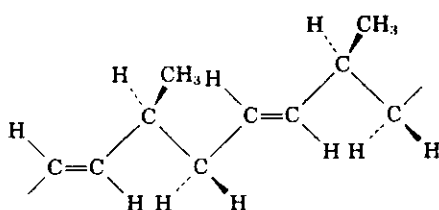
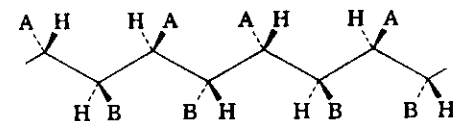
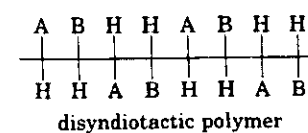
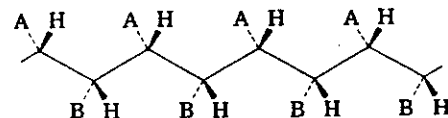
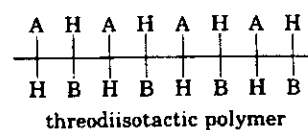
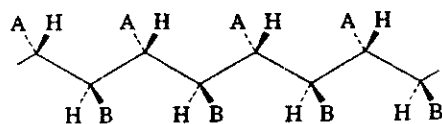
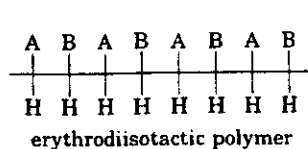
Vol. 10

molecules have equal numbers of the possible configurational units in a random sequence distribution. This can be generalized as follows:

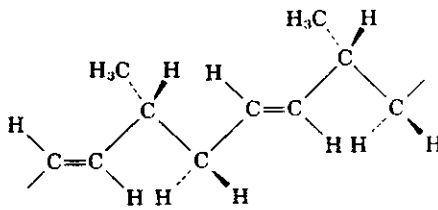
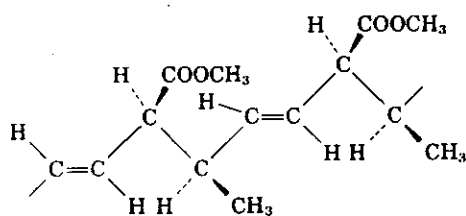
Isotactic:*Syndiotactic:**Atactic:*

Further examples of tactic polymers are

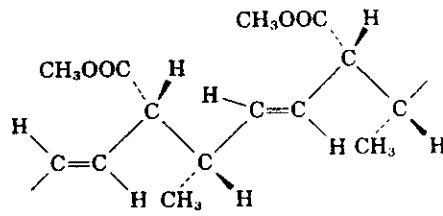




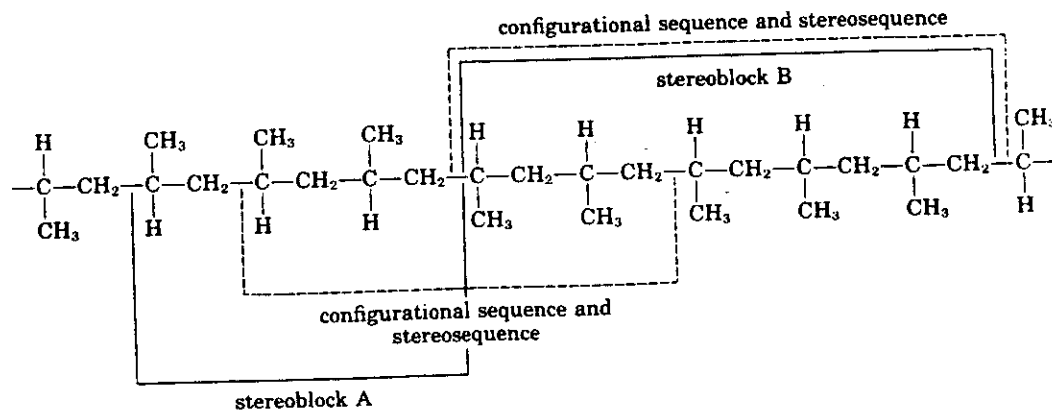
and/or

isotactic poly(3-methyl-*trans*-1-butenylene) or transisotactic poly(3-methyl-1-butenylene)

and/or

diisotactic poly(*threo*-3(methoxycarbonyl)-4-methyl-*trans*-1-butenylene) or transthreodiisotactic poly(3-(methoxycarbonyl)-4-methyl-1-butenylene)

The concept of a stereoblock is illustrated in the following example of a regular poly(propylene) chain, in which the stereoblocks are denoted by \square . The sequence of identical relative configurations of adjacent units that characterizes a stereoblock is terminated at each end of the block. The dashed line \cdots encloses a configurational sequence, which may or may not be identical with a stereoblock.



The published IUPAC document (4) should be consulted for more complex cases and for the notations used to designate conformations of polymer molecules (bond lengths, bond angles, torsion angles, helix sense, isomorphous and enantiomorphous structures, line repetition groups and symmetry elements, etc) as well as for the various stereochemical definitions (see also MICROSTRUCTURE; STEREOREGULAR POLYMERS).

Trade Names and Abbreviations

Because the systematic names of polymers can be cumbersome, trade names and abbreviations are frequently used as a shortcut in industrial literature and

Table 4. List of Abbreviations from the 1986 IUPAC Recommendations^a

PAN	polyacrylonitrile
PCTFE	polychlorotrifluoroethylene
PEO	poly(ethylene oxide)
PETP ^b	poly(ethylene terephthalate)
PE	polyethylene
PIB	polyisobutylene
PMMA	poly(methyl methacrylate)
POM	poly(oxyethylene); polyformaldehyde
PP	polypropylene
PS	polystyrene
PTFE	polytetrafluoroethylene
PVAC	poly(vinyl acetate)
PVAL	poly(vinyl alcohol)
PVC	poly(vinyl chloride)
PVDC	poly(vinylidene dichloride)
PVDF	poly(vinylidene difluoride)
PVF	poly(vinyl fluoride)

^a Ref. 9.

^b The abbreviation PET is commonly used in the literature.

oral communication. For example, the simpler generic name nylon-6,6 for a polyamide, where the first number refers to the number of carbon atoms of the diamine and the second number to that of the diacid fragment, appears often in the literature rather than the systematic name poly(iminoadipoyliminohexamethylene). Useful compilations of trade names for polymers can be found in Refs. 23 and 24.

Perhaps the most widely used shortcut is the use of abbreviations for common industrial polymeric materials. The IUPAC recognizes that there may be advantages in some cases to use abbreviations, but urges that each abbreviation be fully defined the first time it appears in the text and that no abbreviation be used in titles of publications. Because there are inherent difficulties in assigning systematic and unique abbreviations to polymeric structures, only a short list has the IUPAC's official sanction (9,10) (Table 4). ISO has published a more extensive list (25), and the American Chemical Society has compiled a master list of all known abbreviations in the polymer field (26).

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204 NOMENCLATURE

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NONAQUEOUS DISPERSIONS. See COATINGS.

NONCOMBUSTIBLE FABRICS. See FLAMMABILITY.

NONDESTRUCTIVE TESTING. See TEST METHODS.

NON-NEWTONIAN FLOW. See VISCOELASTICITY.

NONWOVEN FABRICS

Survey, 204
Spunbonded, 227

SURVEY

Nonwoven fabrics are porous, textilelike materials, usually in flat sheet form, composed primarily or entirely of fibers assembled in webs (1-3). The fabrics, also called bonded fabrics, formed fabrics, or engineered fabrics, are manufactured by processes other than spinning, weaving, or knitting. The thickness of the sheets may vary from 25 μm to several centimeters, and the weight from 10 g/m^2 to 1 kg/m^2 . A sheet may resemble paper or a woven or knitted fabric in appearance and may have a unique texture or pattern. It may be as compact and crisp as paper or supple and drapable as a conventional textile; it may be resilient or limp. Its tensile properties may be barely self-sustaining or so high that it is impossible to tear, abrade, or damage the sheet by hand. The fiber composition may be one or several types, may be natural or synthetic, from 1-3-mm long to endless. The tensile properties may depend on frictional forces or a film-forming polymer additive functioning as an adhesive binder. All or some of the fibers may be welded by heat or solvent. A scrim, gauze, netting, yarn, or other conventional sheet material may be added to one or both faces, or embedded within as reinforcement. The nonwoven fabric may be incorporated as a component in a composite structure.

Felted fabrics from animal hairs, eg, wool (qv), are not included even though

an-hy-drous \('an,hīdrəs\ *adj* [modif. (influenced by *hydr-*,
hydro- of Gk *anhydros* waterless, fr. *an-* + *-ydros* (fr. *hydōr*,
water) — more at **WATER**]: destitute of water — used of water of
crystallization, dissolved or combined water, adsorbed water

TAB D

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INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY

MACROMOLECULAR DIVISION
COMMISSION ON MACROMOLECULAR NOMENCLATURE*

GENERIC SOURCE-BASED NOMENCLATURE FOR POLYMERS

(IUPAC Recommendations 2001)

Prepared by a Working Group consisting of

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Generic source-based nomenclature for polymers

(IUPAC Recommendations 2001)

Abstract: The commission has already published two documents on the source-based names of linear copolymers and nonlinear polymers; however, in some cases this nomenclature leads to ambiguous names. The present document proposes a generic source-based nomenclature that solves these problems and yields clearer source-based names. A generic source-based name comprises two parts:

- 1) polymer class (generic) name followed by a colon
- 2) the actual or hypothetical monomer name(s), always parenthesized in the case of a copolymer

The formula, the structure-based name, the source-based name, and the generic source-based name of the polymer are given for each example in the document. In some cases, only generic source-based give unambiguous names, for example, when a polymer has more than one name or when it is obtained through a series of intermediate structures. The rules concern mostly polymers with one or more types of functional group or heterocyclic system in the main chain, but to some extent they are also applicable to polymers with side-groups, carbon-chain polymers such as vinyl or diene polymers, spiro and cyclic polymers, and networks.

CONTENTS

1. INTRODUCTION
2. SOURCE-BASED NOMENCLATURE FOR HOMOPOLYMERS
3. GENERIC NOMENCLATURE
 - 3.1 Fundamental principles
 - 3.2 General rules
4. FURTHER APPLICATIONS OF GENERIC NAMES
5. REFERENCES

1. INTRODUCTION

The IUPAC Commission on Macromolecular Nomenclature has published three documents [1–3] on the structure-based nomenclature for polymers that enable most polymers, except networks, to be named. The Commission has also produced two documents [4,5] on the source-based nomenclature of linear copolymers and nonlinear polymers. In general, source-based names are simpler and less rigorous than structure-based names. However, there are cases in which the simplicity of the source-based nomenclature leads to ambiguous names for polymers. For example, the condensation of a dianhydride (A) with a diamine (B) gives first a polyamide-acid, which can be cyclized to a polyimide; however, both products have the same name poly(A-*alt*-B) according to current source-based nomenclature. If the class name of the polymer “amide-acid” or “imide” is incorporated in the name, differentiation is easily accomplished. Even in cases where only a single product is formed, use of the class name (generic name) may help to clarify the structure of the polymer, especially if it is very complex.

Examples of ambiguous names exist also for homopolymers. The source-based name “polybutadiene” does not indicate whether the structure is 1,2-, 1,4-*cis*-, or 1,4-*trans*-; supplementary information is needed to distinguish between the possibilities.

It is the objective of the present document to introduce a generic nomenclature system to solve these problems, and to yield better source-based names.

Most trivial names, such as polystyrene, are source-based names. Hitherto, the Commission has not systematically recommended source-based names for homopolymers because it considered that the more rigorous structure-based names were more appropriate for scientific communications. However, since the publication of "Nomenclature of Regular Single-Strand Organic Polymers" in 1976, scientists, in both industry and academia, have continued to use trivial names. Even the Commission itself adopted (1985) a source-based nomenclature for copolymers owing to its simplicity and practicality. Based on these facts, the Commission has now decided to recommend source-based nomenclature as an alternative official nomenclature for homopolymers. In this document, the rules for generating source-based names for homopolymers are described. Consequently, source-based and structure-based names are available for most polymers.

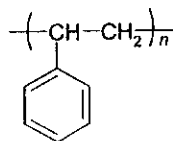
Names of the monomers in the source-based names of polymers should preferably be systematic but they may be trivial if well established by usage. Names of the organic groups, as parts of constitutional repeating units (CRU) in structure-based names, are those based on the principles of organic nomenclature and recommended by the 1993 *A Guide to IUPAC Nomenclature of Organic Compounds* [6].

2. SOURCE-BASED NOMENCLATURE FOR HOMOPOLYMERS

RULE 1

The source-based name of a homopolymer is made by combining the prefix "poly" with the name of the monomer. When the latter consists of more than one word, or any ambiguity is anticipated, the name of the monomer is parenthesized.

Example 1.1



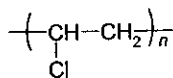
Source-based name:

polystyrene

Structure-based name:

poly(1-phenylethylene)

Example 1.2



Source-based name:

poly(vinyl chloride)

Structure-based name:

poly(1-chloroethylene)

3. GENERIC NOMENCLATURE

3.1 Fundamental principles

The basic concept for generic source-based nomenclature is very simple; just add the polymer class name to the source-based name of the polymer. Addition of the polymer class name is frequently

OPTIONAL; in some cases, the addition is necessary to avoid ambiguity or to clarify. However, the addition is undesirable if it fails to add clarification.

The system presented here can be applied to almost all homopolymers, copolymers, and others, such as networks. However, generic source-based nomenclature should not be considered as a third nomenclature system to be added to the other two systems of nomenclature; it must be considered as an auxiliary system and a simple extension of current source-based nomenclature. When the generic part of the name is eliminated from the name of a polymer, the well-established source-based name remains.

3.2 General rules

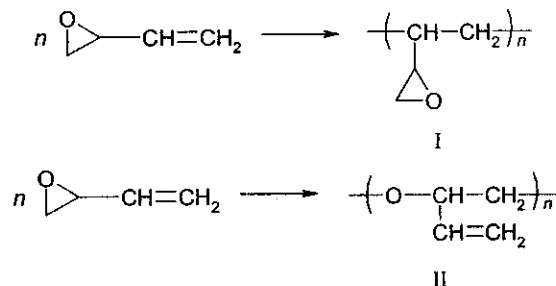
RULE 2

A generic source-based name of a polymer has two components in the following sequence: (1) a polymer class (generic) name (polyG) followed by a colon and (2) the actual or hypothetical monomer name(s) (A, B, etc.), always parenthesized in the case of a copolymer. In the case of a homopolymer, parentheses are introduced when it is necessary to improve clarity.

polyG:A polyG:(B) polyG:(A-co-B) polyG:(A-alt-B)

- Note 1** The polymer class name (generic name) describes the most appropriate type of functional group or heterocyclic ring system.
- Note 2** All the rules given in the two prior documents on source-based nomenclature [4,5] can be applied to the present nomenclature system, with the addition of the generic part of the name.
- Note 3** A polymer may have more than one name; this usually occurs when it can be prepared in more than one way.
- Note 4** If a monomer or a pair of complementary monomers can give rise to more than one polymer, or if the polymer is obtained through a series of intermediate structures, the use of generic nomenclature is essential (see examples 2.1, 2.3, and 2.4).

Example 2.1



Generic source-based name:

- I. polyalkylene:vinylloxirane
- II. polyether:vinylloxirane

Source-based names:

- I and II have the same source-based name: poly(vinylloxirane).

Structure-based names:

- I. poly(1-oxiranylethylene)
- II. poly[(oxy(1-vinylethylene)]

Generic source-based nomenclature for polymers

1515

Example 2.2



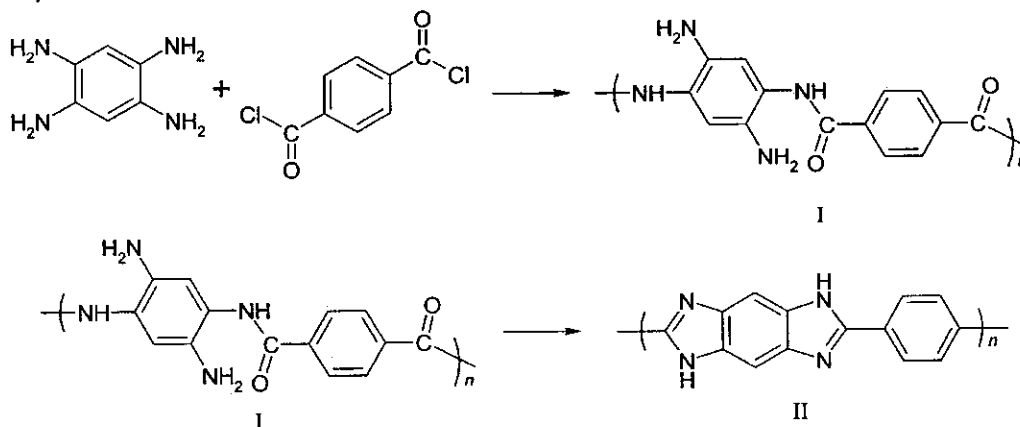
Generic source-based name:

polyoxadiazole:(4-cyanobenzonitrile *N*-oxide)

Structure-based name:

poly(1,2,4-oxadiazole-3,5-diyl-1,4-phenylene)

Example 2.3



Generic source-based name:

I. polyamide:[(terephthaloyl dichloride)-*alt*-benzene-1,2,4,5-tetramine]II. polybenzimidazole:[(terephthaloyl dichloride)-*alt*-benzene-1,2,4,5-tetramine]

Source-based name:

I and II have the same source-based name:

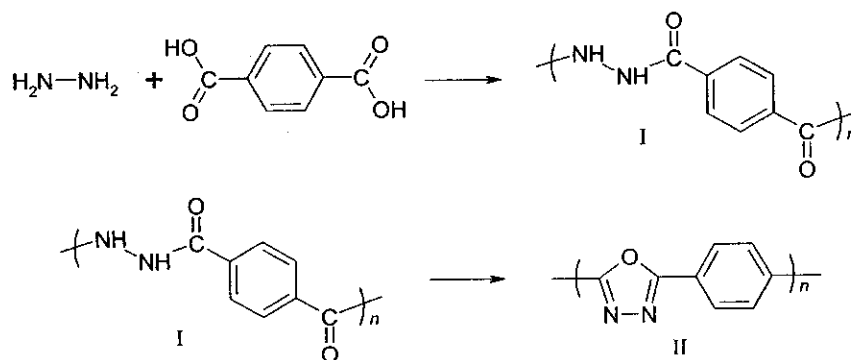
poly[(terephthaloyl dichloride)-*alt*-benzene-1,2,4,5-tetramine]

Structure-based names:

I. poly[imino (2,5-diamino-1,4-phenylene)iminoterephthaloyl]

II. poly[(1,5-dihydrobenzo[1,2-*d*:4,5-*d'*]diimidazole-2,6-diyl)-1,4-phenylene]

Example 2.4



Generic source-based names:

I. polyhydrazide:[hydrazine-*alt*-(terephthalic acid)]II. polyoxadiazole:[hydrazine-*alt*-(terephthalic acid)]

1516

E. MARÉCHAL AND E. S. WILKS

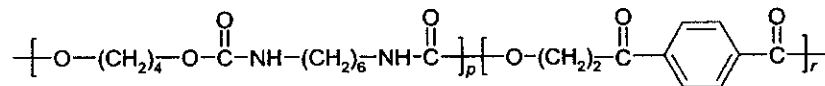
Source-based name:

I and II have the same source-based name: poly[hydrazine-*alt*-(terephthalic acid)]

Structure-based names:

I. poly(hydrazine-1,2-diylterephthaloyl)

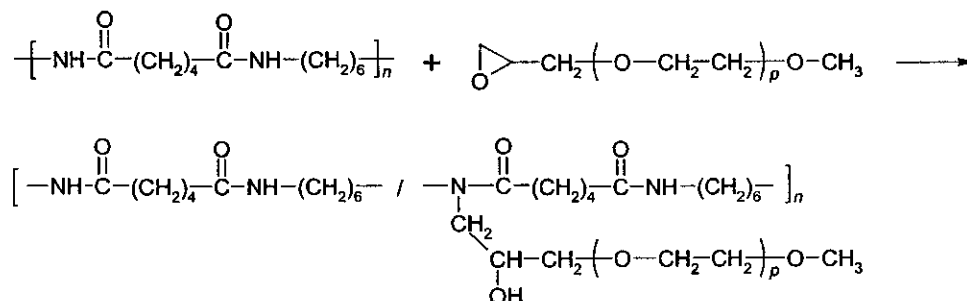
II. poly(1,3,4-oxadiazole-2,5-diyl-1,4-phenylene)

Example 2.5

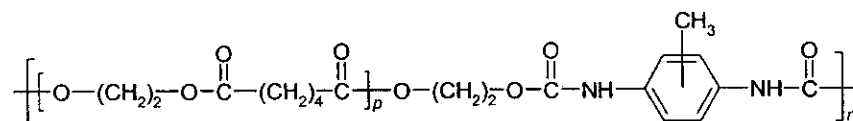
Generic source-based names:

polyurethane:[butane-1,4-diol-*alt*-(hexane-1,6-diyl diisocyanate)]-*block*-polyester:[(ethylene glycol)-*alt*-(terephthalic acid)]

Structure-based name:

poly(oxybutane-1,4-dyloxycarbonyliminohexane-1,6-diyliminocarbonyl)-*block*-poly(oxyethyleneoxyterephthaloyl)**Example 2.6**

Generic source-based name:

polyamide:[hexane-1,6-diamine-*alt*-(adipic acid)]-*graft*-polyether:(ethylene oxide)**Note 5** It is assumed that this reaction is limited to only one graft for each CRU.**RULE 3**When more than one type of functional group or heterocyclic system is present in the polymer structure, names should be alphabetized; for example, poly(GG'):(A-*alt*-B).**Note 6** It is preferable, but not mandatory, to cite all generic classes.**Example 3.1**

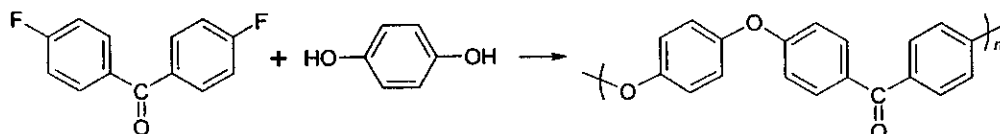
Generic source-based name:

polyesterurethane:{ α,ω -dihydroxyoligo[(ethylene glycol)-*alt*-(adipic acid)]-*alt*-(2,5-tolylene diisocyanate)}

Structure-based name:

poly{[oligo(oxyethyleneoxyadipoyl)]oxyethyleneoxycarbonylimino(x-methyl-1,4-phenylene)iminocarbonyl)}

Example 3.2



Generic source-based name:

polyetherketone:(4,4'-difluorobenzophenone-*alt*-hydroquinone)

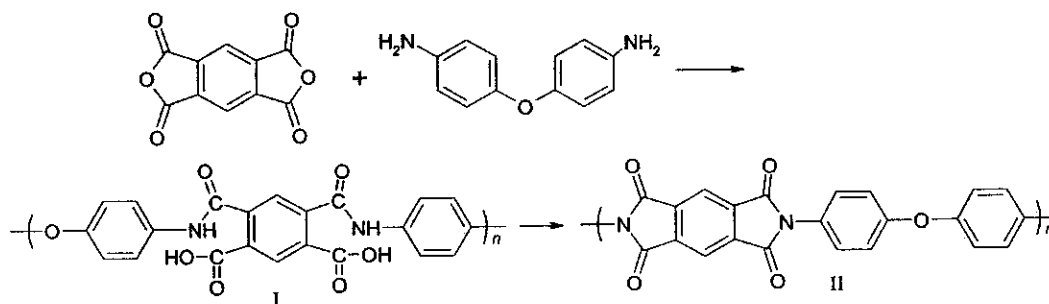
Structure-based name:

poly(oxy-1,4-phenyleneoxy-1,4-phenylenecarbonyl-1,4-phenylene)

RULE 4

Polymer class names relevant only to the main chain are specified in the name; names of side-chain functional groups may also be included after a hyphen if they are formed during the polymerization reaction.

Example 4.1



Generic source-based names:

I. poly(amide-acid):[(pyromellitic dianhydride)-*alt*-(4,4'-oxydianiline)]
(Both carboxy groups result from the polymerization reaction.)

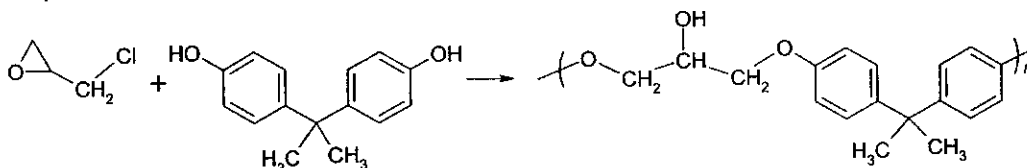
II. polyimide:[(pyromellitic dianhydride)-*alt*-(4,4'-oxydianiline)]

Structure-based names:

I. poly[oxy-1,4-phenyleneiminocarbonyl(4,6-dicarboxy-1,3-phenylene)carbonylimino-1,4-phenylene]

II. poly{[(5,7-dihydro-1,3,5,7-tetraoxobenzo[1,2-*c*:4,5-*c'*]dipyrrole-2,6(1*H*,3*H*)-diyl)-1,4-phenyleneoxy-1,4-phenylene]}

Example 4.2



Generic source-based names:

poly(ether-alcohol):(epichlorohydrin-*alt*-bisphenol A)

Structure-based name:

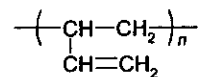
poly[oxy(2-hydroxypropane-1,3-diyl)oxy-1,4-phenylene(1-methylethane-1,1-diyl)-1,4-phenylene]

1518

E. MARÉCHAL AND E. S. WILKS

RULE 5

In the case of carbon-chain polymers such as vinyl polymers or diene polymers, the generic name is to be used only when different polymer structures may arise from a given monomeric system.

Example 5.1

Generic source-based name:

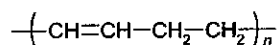
polyalkylene:(buta-1,3-diene)

Source-based name:

poly(buta-1,3-diene)

Structure-based name:

poly(1-vinylethylene)

Example 5.2

Generic source-based name:

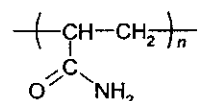
polyalkenylene:buta-1,3-diene

Source-based name:

poly(buta-1,3-diene)

Structure-based name:

poly(but-1-ene-1,4-diyl)

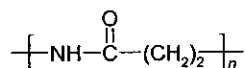
Example 5.3

Generic source-based name:

polyalkylene:acrylamide

Structure-based name:

poly[1-(aminocarbonyl)ethylene]

Example 5.4

Generic source-based name:

polyamide:acrylamide

Structure-based name:

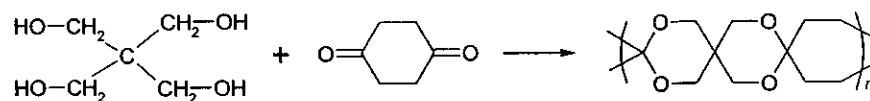
poly[imino(1-oxopropane-1,3-diyl)]

Note 7 The terms polyalkylene and polyalkenylene have been defined in ref. 7, p. 149.

4. FURTHER APPLICATIONS OF GENERIC NAMES

Generic source-based nomenclature can be extended to more complicated polymers such as spiro and cyclic polymers and networks.

Example 6.1



Generic source-based name:

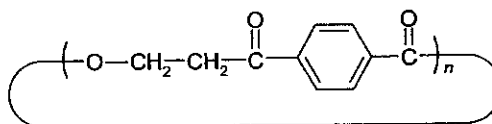
polyspiroketal: {[2,2-bis(hydroxymethyl)-propane-1,3-diol]-*alt*-cyclohexane-1,4-dione}

or polyspiroketal:(pentaerythritol-*alt*-cyclohexane-1,4-dione)

Structure-based name:

poly[2,4,8,10-tetraoxaspiro[5.5]undecane-3,3,9,9-tetrayl-9,9-bis(ethylene)]

Example 6.2

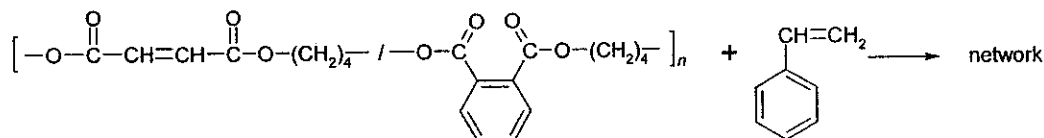


Generic source-based name:

cyclo-polyester:[(ethylene glycol)-*alt*-(terephthalic acid)]

Note 8 There is no IUPAC nomenclature for cyclic polymers.

Example 6.3



Generic source-based name:

polyester:{butane-1,4-diol-*alt*-[(maleic anhydride);(phthalic anhydride)]}-*net*-polyalkylene:
(maleic anhydride)-*co*-styrene]

5. REFERENCES

1. "Nomenclature of regular single-strand organic polymers, 1975", *Pure Appl. Chem.* **48**, 373–385 (1976). Reprinted as chapter 5 in Ref. 7.
2. "Nomenclature of regular double-strand (ladder and spiro) organic polymers 1993", *Pure Appl. Chem.* **65**, 1561–1580 (1993).
3. "Structure-based nomenclature for irregular single-strand organic polymers 1994", *Pure Appl. Chem.* **66**, 873–889 (1994).
4. "Source-Based Nomenclature for Copolymers 1985", *Pure Appl. Chem.* **57**, 1427–1440 (1985). Reprinted as chapter 7 in Ref. 7.
5. "Source-based nomenclature for non-linear macromolecules and macromolecular assemblies", *Pure Appl. Chem.* **69**, 2511–2521 (1997).
6. *A Guide to IUPAC Nomenclature of Organic Compounds*, R. Panico, W. H. Powell, J-C. Richer (Eds.), Blackwell Scientific Publications, Oxford (1993).
7. *Compendium of Macromolecular Nomenclature*, W. V. Metanomski (Ed.), Blackwell Scientific Publications, Oxford (1991).

TAB E

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF MASSACHUSETTS

DePuy Mitek, Inc., a
Massachusetts Corporation,

Plaintiff,

vs.

CIVIL ACTION
NO. 04-12457 PBS

Arthrex, Inc., a Delaware
Corporation,

Defendant.

DEPOSITION OF: DONALD GRAFTON
DATE: March 14, 2006
TIME: 8:38 a.m. to 1:23 p.m.
LOCATION: The Ritz Carlton Golf Resort
2600 Tiburon Drive
Naples, FL 34112
TAKEN BY: Plaintiff
REPORTER: Deborah A. Krotz, RPR, CRR
VIDEOGRAPHER: Gene Howell, CLVS

<p style="text-align: right;">50</p> <p>1 ultra-high molecular weight polyethylene or if it was 2 braided or -- 3 A. It's been too long ago. I can't tell you that. 4 Q. And your idea was to use the ultra-high molecular 5 weight polyethylene as a suture? 6 A. Yes. 7 Q. Okay. And you had Mr. Hallett make a Size 2, I 8 think you said? 9 A. Yes. 10 Q. Okay. Can you describe the construction of that 11 first -- 12 A. I don't remember now. It's been too long. 13 Q. Was it all ultra -- ultra-high molecular weight 14 polyethylene? 15 A. Initially, yes, as a test prototype material. 16 Q. Was it braided? 17 A. Yes. 18 Q. Was it an eight-carrier or a sixteen-carrier? 19 A. I don't remember. 20 Q. You said it was a Size 2 though? 21 A. Yes. 22 Q. So it was a Size 2 ultra-high molecular weight 23 polyethylene braided suture that did not have PET? 24 A. For the initial prototype material, that's 25 correct.</p>	<p style="text-align: right;">52</p> <p>1 Q. Knot security test? 2 A. Yes. 3 Q. Was that the test we drew in Exhibit Number 421? 4 A. That's correct. 5 Q. Okay. And you said the strength was excellent. I 6 believe, of the initial prototype, but the knot slippage 7 was poor; is that right? 8 A. Yes. 9 Q. Okay. When you say the slippage was poor of the 10 initial prototype, what do you mean? 11 A. Less than the tensile strength capability of the 12 existing Arthrex product. 13 Q. So the knot slippage was less than the Tevdek 14 suture? 15 A. Yes. 16 Q. And it was -- knot slippage was such that it was 17 determined that the 100 percent ultra-high molecular 18 weight polyethylene suture prototype wasn't suitable to be 19 developed? 20 A. That's correct. Yes. 21 Q. Okay. Ultra-high molecular weight polyethylene, 22 you said the knot slippage was poor? 23 A. (Witness nods head affirmatively). 24 Q. Ultra-high molecular weight polyethylene, is that 25 a lubricious material?</p>
<p style="text-align: right;">51</p> <p>1 Q. Okay. And it didn't have nylon or any other 2 material braided with it? 3 A. No. 4 Q. So the initial prototype was a ultra-high 5 molecular weight polyethylene braided suture prototype, if 6 you will? 7 A. Yes. Size 2. 8 Q. Size 2. And was the initial prototype, was it 9 coated? 10 A. I don't remember. 11 Q. Okay. Do you know if the initial prototype went 12 through any other manufacturing process like stretching or 13 heating, twisting? 14 A. I don't recall. 15 Q. Was the initial prototype 100 percent ultra-high 16 molecular weight polyethylene? 17 A. For the fourth time, yes. 18 Q. Okay. And you tested the initial prototype that 19 was 100 percent ultra-high molecular weight polyethylene 20 with Dr. Burkhart and Dr. Chen? 21 A. Dr. Casey Chen, correct. 22 Q. Okay. And the test that you conducted with Dr. 23 Burkhart and Dr. Chen on the ultra-high molecular weight 24 polyethylene was a knot strength test? 25 A. Knot security.</p>	<p style="text-align: right;">53</p> <p>1 A. Yes. 2 Q. And was the knot slippage of this ultra-high 3 molecular weight polyethylene poor security because of the 4 lubricity of polyethylene? 5 A. Yes. 6 Q. Yes? 7 A. Yes. 8 Q. So then you came up with the idea to braid PET 9 with the ultra-high molecular weight polyethylene to 10 reduce the knot slippage? 11 A. Yes. 12 Q. And when you say knot slippage, we're referring 13 to this knot security test? 14 A. Yes. 15 Q. So are we using the terms knot slippage and knot 16 security interchangeably here? 17 A. You are, yes. 18 Q. In your testimony? 19 A. Yes. 20 Q. So the knot security of the 100 percent 21 ultra-high molecular weight polyethylene was poor, the 22 prototype; right? 23 A. Yes. 24 Q. And your idea was to add the PET and to improve 25 the knot security?</p>